# Proceedings of the I·R·E

## a Journal

of the Theory, Practice, and Applications of Electronics and Electrical Communication

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DECEMBER, 1944

VOLUME 32 NUMBER 12

Philosophy of Design

Frequency-Modulation Receiver

Electronics and Medical Science

Electrical Glass

I-F System for F-M Receivers

Saw-Tooth-Current Oscillator

Network Response to Impulse

Directive-Array Calculator

The Institute of Radio Engineers

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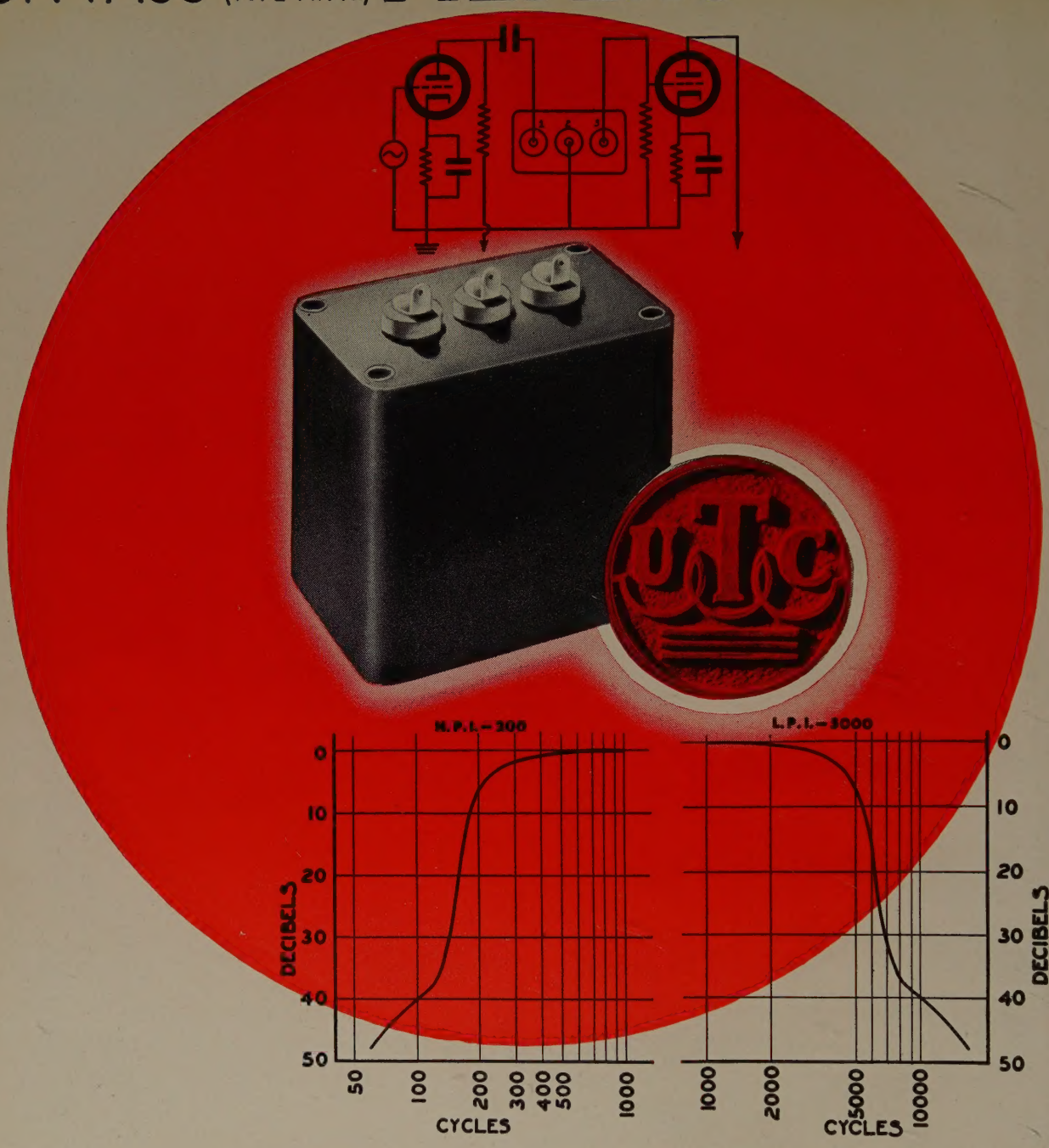


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# Electronic Papers

This is a proposal that a still further increased number of papers dealing with electronic apparatus and methods shall promptly be submitted for publication in the PROCEEDINGS OF THE I.R.E. in order to promote the rapid development of the radio-and-electronic field and to place before the readers of the PROCEEDINGS the fundamental steps taken in that domain.

During the several decades of its existence, the contents of the PROCEEDINGS OF THE I.R.E. have faithfully mirrored the trends and accomplishments of current engineering within the scope of the Institute. Its pages have been at once a history of the art, a recital of current practice, and an introduction to future developments. The underlying policy continued in force, even in the troubled days of World War I. It remains unchanged in the far more turbulent period of World War II.

It is timely to redefine the scope of The Institute of Radio Engineers and accordingly of its PROCEEDINGS. Briefly, these interests cover the field of radio technique and its applications. This realm of thought has been termed the radio-and-electronic field. It naturally includes radio communication in all its aspects, both two-way and one-way. The latter type is represented by that major method of mass communication: radio broadcasting. Telegraphy, telephony, facsimile, teleprinting, and television are the broad method aspects of the radio field. Transmission, propagation, and reception of any form of electromagnetic waves—including the versatile extremely high-frequency oscillations—are necessarily involved.

But applied radio technique extends further, and into all of what may be termed the field of electronics. A wide variety of phenomena, practices, and devices have been included under that heading. Methods of intricate, high-speed, and unusually accurate control of physical effects have been involved. Many circuit elements have been drawn from the field of pure radio, with minor modification, to meet the design needs of electronic devices. Amplifiers, oscillators, detectors, and their associated circuit assemblies are normally used. Photocells, capacitance-sensitive systems, and even television equipment have found their way into electronic use. In fact, the heterogeneity of radio-and-electronic devices and methods is one of their distinguishing characteristics!

The PROCEEDINGS OF THE I.R.E. can and will take its proper place in contributing substantially to the development of all electronic aspects of its field. An increasing number of basic papers dealing with the corresponding topics will be found in its pages.

There will be required co-operation on the part of the membership of the Institute to maintain this publication policy in effective fashion. Accordingly, those workers who develop electronic devices or methods which are at this time without direct military significance are urged to prepare papers descriptive of their work and to submit these for publication in the PROCEEDINGS.

The PROCEEDINGS will always represent the integrated engineering thought, technical effort, and group loyalty of the members of the Institute. It will stand as a symbol of their professional aspirations and accomplishments. It is earnestly hoped that the Institute will find a prompt and major response to this appeal for the early submission of papers dealing with the electronic aspects of the field of engineering activity of the members and their Institute.

*The Editor*

# Major General Harry C. Ingles

Major General Harry C. Ingles, who was appointed Chief Signal Officer of the Army on July 1, 1943, has been connected with communication work in the Army since the beginning of World War I and has had a wide and varied career in the Army.

He was graduated from West Point with a B.S. degree in 1914, and during the last war he was in charge of the training of Signal Corps officers.

Since the last war he has had various communication assignments, including Signal Officer, Philippine Division; Director, Signal Corps School; instructor in communication at the Command and General Staff School; Signal Officer, Third Army; and Signal Officer, Caribbean Defense Command.

Other important duties to which he has been assigned include War Department General Staff; Chief of Staff, Caribbean Defense Command, for which duty he was awarded the Distinguished Service Medal; and Deputy Commander, European Theater of Operations.

General Ingles is a graduate of the Army Signal School and the Army War College, and a distinguished graduate of the Command and General Staff School.

The electronic engineers, as well as the communication engineers, have played an outstanding part in the present world conflict. They have both contributed a host of devices of significance to the Military Services. It is therefore with deep gratification that the Institute presents to the readers of the PROCEEDINGS OF THE I.R.E. a guest editorial dealing with the work of the members of the Institute and coming from the pen of the Chief Signal Officer of the United States Army, Major General Harry C. Ingles. This message came with the best wishes of General Ingles to the entire membership of The Institute of Radio Engineers—and these wishes are certainly heartily reciprocated.

*The Editor*

# Radio-and-Electronic Engineers in War and Peace

MAJOR GENERAL HARRY C. INGLES

When the history of World War II is written, it will be found that although little publicity was given to the work engaged in during hostilities by radio and electronic engineers, it was the painstaking research activities and patriotic devotion to duty of these brilliant scientists which materially hastened the final Allied victory.

Following on the heels of the Pearl Harbor attack, our country called for help, and many leading radio-and-electronic engineers, most of them members of The Institute af Radio Engineers, were prompt in their response. Today the United States is the communications center of the world and much of the credit must go to the excellent co-operation of these men of science.

In these days of whirlwind warfare, with entire armies moving at unbelievable speed, signal communications are of paramount importance in directing our gigantic offensives. The Signal Corps, whose principal mission is to insure swift and reliable communication among all elements of the Army from the high command in Washington to the most advanced outpost, employs every serviceable means to achieve that accomplishment.

But it is in the field of radio and electronics that the Signal Corps has attained pre-eminence in signal communications. Many amazing items of signal communications equipment have resulted from the research activities of radio-and-electronic engineers in co-operation with Signal Corps engineers. For the time being much of this equipment must remain a military secret. However, members of The Institute of Radio Engineers may well feel proud of their contribution to the successful performance of this equipment on battlefields in every quarter of the globe, and to the winning of the great conflict now raging. Without their scientific aid, the magnificent victories now being won by our forces might not have been possible.

The Signal Corps has trained thousands of men in the basic principles of radio-and-electronic engineering in order to provide personnel to operate and repair the intricate and astounding signal equipment now helping our men to win victories all over the world. Radio-and-electronic engineers, by lending their knowledge of this vital science, helped to improve and perfect this vast training program.

Thus the radio industry will have a large reservoir of trained personnel upon which to draw for its postwar expansion, which will eclipse anything it had attained prior to the opening of hostilities in the Far East.

Radio-and-electronic engineers now have a big job in helping us to win the war. But they will also have a job after victory in helping to set up new applications of the devices they aided in developing for military purposes. But what is more important, members of The Institute of Radio Engineers, when peacetime comes, can render a patriotic service to our country by helping it to grow even stronger, through science, so that no aggressor, or combination of them, may ever again threaten our security.

# Frederick B. Llewellyn

Chairman, Papers Committee

Frederick B. Llewellyn was born in New Orleans, Louisiana, on September 16, 1897. In 1915 Dr. Llewellyn took a course at the old Marconi School for Wireless Operators. Off and on, Dr. Llewellyn put in about three years in the merchant marine, plus the better part of a year in the Navy during the 1917–1918 outbreak.

He was graduated from Stevens Institute of Technology in 1922, where he took special courses under Professor Alan Hazeltine. A year was then spent as laboratory assistant to Dr. F. K. Vreeland and in 1923 he joined the technical staff of the Western Electric Company, later transferring to the Bell Telephone Laboratories when it was formed in 1925. His work was then concerned with the long-wave transatlantic telephone, operating through Rocky Point, L. I. From 1924 to 1928 he attended graduate classes at Columbia and in 1928 received the Ph.D. degree.

In 1929 the ship-to-shore telephone service was inaugurated with the *S. S. Leviathan* as the first to open for public service. Dr. Llewellyn was one of the engineers who carried out the development of the shipboard installation and made a number of voyages on the famous vessel. Ten years later a reunion luncheon was held at which Commodore Cunningham was presented with the telephone handset which had been in his cabin at the opening, when he was skipper of the ship.

On shore once more, Dr. Llewellyn's next work was the investigation of noise in vacuum tubes and of constant-frequency oscillators. This was followed by a study of the action of vacuum tubes at very high frequencies. In 1936 he was awarded the Morris Liebmann Memorial prize for his results on high-frequency electronics and on constant-frequency oscillators.

A member of the Electronics Committee for many years, Dr. Llewellyn was especially active in connection with the Electronics Conferences which were held for the years just preceding the war. With the retirement of Dr. William Wilson as Chairman of the Papers Committee, he succeeded to that post. For the past two years he has been on the Executive Committee, where his special assignment is to promote the welfare of the technical committees. He became an Associate Member of the Institute of Radio Engineers in 1923 and was transferred to the Fellow grade in 1938.

# Philosophy of Design*

## The Foundation for Better Planning

C. M. ASHLEY†, NONMEMBER, I.R.E.

*Summary*—**Success of an industrial research and development organization depends not only upon the ability and intelligence of its members and on the effectiveness of their organization. Equally important is a proper working philosophy as the guide to action for each individual and for the group as a whole. The development engineer must deal with nature in a most imperfect state where theory is frequently hidden from sight by the complexity of interactions involved. Problems with which he wrestles are usually too complex for exact analysis. Experience teaches the development man things which his intellect would never have told him. He learns the proper balance between daring and caution, idealism and realism, theory and practice. His way of thinking must be pragmatic in character, based upon an evaluation of risks and the probabilities of a given situation.**

### This Thing Called Perfection

THE perfectionist is never happy as a development engineer. He quickly learns that perfection in any detail is difficult to obtain and requires an inordinate amount of time. He is soon forced to one of two alternatives. Either he perseveres, seeking perfection, in which case he ceases after a time to be a useful development engineer, or else he gives up his ideal of perfection, in which case he is no longer a perfectionist. At the other extreme is the man who is easily satisfied with an imperfect achievement and never realizes the possibilities of the thing which he is developing. Less complacent competition sweeps past this man.

Perhaps the ideal attitude is that of the deferred perfectionist. While never wholly satisfied with present forms, he realizes perfection is an objective which cannot completely be attained and is content to strive for worthwhile improvements. The problem of deciding when a development has reached a practical stopping point requires fine judgment. The design must be viewed objectively from the point of view of both the user and the salesman. Two questions must be asked: First, is the equipment developed commercially practical? Second, have possibilities of trouble been reasonably eliminated?

One reason why perfection cannot be taken too seriously is that it doesn't stay put. At best it is a mental image. Too often the engineer finds that his mental image has no reflection in reality, that a perfectly conceived and executed design leaves the field cold when some purely practical objection, such as cost or lack of market, acts as an insuperable bar to acceptance. Another quality of perfection is its growth. As progress is made our imagination reaches out still further ahead. Our ideas of perfection in equipment are constantly being tempered and conditioned by changing outside influences such as customer reaction, practical workability, or competition.

So the wise development man recognizes perfection as that something within himself which makes him dissatisfied with present forms, rather than an absolute objective. He learns to control this dissatisfaction to yield maximum returns for the time and money with which he has to work.

### When Trouble Comes

Since perfection is never achieved, the development engineer is constantly beset by troubles. Equipment design is a strange mixture of theory and practice and often the theory comes only as the rationalization of recognized practice. In many cases it is only by repeated trials of a new design element that success can ultimately be won out of failure. Even the minor modification of a design in a thoroughly explored field may be beset by trouble. Consider the new model of an automobile, as an example. Let the motor manufacturer change anything more fundamental than the decoration on the hood and he brings down on himself a host of "weaknesses" despite endless trials in the laboratory, proving ground, and on the road. If this can happen, how much greater is the danger of trouble in a field not nearly so well stabilized nor able to give a new design adequate advance trial? What chance of being free from troubles has a new design, even when relatively simple, when put out with no field trials at all?

Trouble has another characteristic. No matter how successful 999 of 1000 elements of a machine are, if the one remaining part gives trouble that is all that matters. A man may have a car whose motor functions perfectly but he is still thoroughly annoyed by a weak ignition system, a short-circuited starter, or a grabbing clutch. Yet the "bugs" in that car may amount to only one hundredth of one per cent of the design problems which have been solved successfully.

What attitude must be taken? First, trouble must be expected from any change, however small. Second, the likelihood of trouble increases with the magnitude and with the novelty of the change. Third, the chances of catching the trouble in the laboratory stage depend upon the extent and intelligence of the proof tests. Fourth, no amount of proof-testing will catch all of the troubles. Fifth, the wise general always lays his plans for a retreat before he starts his advance.

When a change is made, ask three questions: One, what are the chances of trouble? Two, how can the trouble be discovered? Three, what alternatives are there in case trouble develops? Regarding the third,

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† Product Development Engineer, Carrier Corporation, Syracuse 1, New York.

perhaps there are other methods for achieving the same result that do not seem quite as cleanly designed but which may be less novel, thus safer. Again, the changed part may be subdivided so that replacement is less expensive. Or particularly easy access might be arranged to cut the cost of a field repair.

The role of the development engineer becomes very much like that of the actuary who tries to gage the magnitude of the risk and sets premiums accordingly. Where the production of a machine part is small, it may not be expensive to take large risks. Where the risk possibility is great, the production must not be permitted to grow too large before extensive tests have proved the new design and reduced the risk to a minimum.

One of the most difficult psychological problems is for a man accustomed to designing for small-quantity production, to shift to designing for mass production. Where before he had the utmost freedom in making changes immediately as experience dictated, now he must stop to consider questions of cost, interchangeability, field replacement, confusion in manufacturing and marketing, and a host of others.

There is one other aspect of trouble that certainly deserves mention. It seldom or never occurs where it is expected. This is popularly recognized and is not so difficult to understand when it is remembered that anticipated trouble is usually guarded against. It is the unanticipated trouble against which we cannot protect ourselves. Still, we know from experience that we must expect it and prepare to meet it from whatever quarter it may come—by keeping designs as flexible and adaptable as is in any way consistent with the factors of cost and results.

## The Time Factor

Pure research does not generally recognize time as one of its limitations. Development, on the other hand, meets constant pressure from management to conform its projects to rigid time schedules. Frequently these schedules are dictated not by the time required to carry on the development in an orderly manner, but by the exigencies of the commercial situation, such as competition, production demands, sales needs. It is hard for people outside of the development group to understand why schedules cannot be set up and met, and it is equally hard for those within to set them up and meet them.

Any sort of schedule assumes the success of each step and of the development as a whole, for failure would inevitably retard the work. Actually, however, failure is the customary initial reward of development. In fact, design engineers meet with so many failures in this line of business that they have to be optimists by nature. Otherwise they wouldn't have the courage to keep plugging. Success comes as a rule out of a series of time-consuming failures.

Most developments must fulfill not only one objective, but dozens simultaneously, such as cost, power demand, weight, space occupied, accessibility, quietness, good appearance, and reliability. The failure to meet any one of these may result in failure of the design as a whole. After extensive study it may be found that the objectives are unattainable. They must then be restated and the work started all over again. It is not to be wondered, therefore, that development problems, even those along conventional lines, should be hard to schedule. As for the radically new things, schedules had best be forgotten until some success becomes assured.

Every orderly time estimate of a development is based upon the summation of the time estimates for each separate step. You may allow for failures by figuring on one, three, or five trials to reach a successful solution of a given step, but there is no assurance whatever that this will be the number actually required.

It is commonplace to observe how simple an accomplished result seems compared with the labor and circumlocutions by which it was reached. Experience seems to indicate that developments take about three times as long as there seems any good reason that they should take. But it does not do to set up a schedule which allows this extra time for each step, since then the development engineer unconsciously plans a more exhaustive study which uses up more than the time allowed. For the development as a whole this becomes cumulative. The best plan is to set up each step, giving it a reasonable allowance above the requirements visualized at the start of the development. Then, for the development as a whole, an extra time allowance as taught from experience should be made to cover the remaining contingencies.

Savings in time required to consummate a development can be made through more intelligent planning and execution, that is, better organization. This should be the constant aim of a development staff. Too often, however, the development engineer or director is swayed by commercial exigencies into feeling that in a particular case he can "beat the game." He is customarily disappointed. Even short-circuiting the usual procedure seldom helps him in the long run. Although he may be able to complete a development, he is later forced by unfavorable developments from the field to return to his unfinished task.

Time for design is one of the most important factors in the success of an industrial organization. There is no substitute for it. Both management and design engineers must give it due consideration in laying plans.

## Development Planning

Planning is the lubricant that keeps a development organization running smoothly. Where proper plans are not made, the essential ingredient, time, is out of phase and the result is more likely to be chaos than accomplishment. The planning must be of three types. First, each development project must be planned so as to arrive at a satisfactory state of conclusion at the desired time. This involves the marshalling of resources and

men and working out the time required. In general, all developments follow the same pattern, with variations caused by the magnitude of the design problems and production.

Next comes the planning of the whole development program. Here, all of the projects compete to some extent for the services of the shop, draftsmen, and engineers. In this program must be found some way to relieve the "bottlenecks" wherever they occur.

Finally, there is the problem of the long-term planning of the product engineering of the company. No company would think of operating without some sort of a budget, even though it knew that the budget would not be followed in all details. In the budget would be an account for the depreciation of all of the physical assets of the company: the machinery, the inventory, and the plant. Yet the designs of the products which it makes are seldom considered in depreciation. Some designs may have a useful life of ten or twenty years, but it is normal to expect a life of not more than one to three years before minor changes must be made, and no more than five before something fairly radical is required. In many lines the customer expects, and gets, a new design every year, even though the changes are mostly in the external appearance and gadgets, and the "revolutionary advances" come from the publicity department. It usually takes the better part of a year from the time a minor redesign is approved until it is rolling down the production line, and for a major redesign it may be one to five years, or more. For this reason, it is not enough to wait until some competitor brings out a new design and then try to match or better it.

What this adds up to is that a company, in order to stay in the running, must constantly apply fresh study and effort to each of its lines and must be ready to bring out of the laboratory, at the right moment, new models to keep abreast of competitive progress. For success in this, more time than seems necessary will be taken, troubles will bring their headaches, and the work probably won't be perfect when finished. It is the development man's unique privilege to expect, understand and admit these things. And development work can be soundly organized only by men who base their judgment and planning on the underlying abstract factors.

## Ideas[1]

Ideas are the stuff from which new designs are spun. Everyone has had ideas, has put ideas into practice, and has listened to the ideas of others. Yet few people ever stop to consider just what an idea is. Its nature is generally misunderstood. For instance, it is commonly supposed that the number of ideas is limited, at least concerning any one subject, and that only a few persons are endowed with the mystic genius of idea creation. This is not so. Consider Rube Goldberg and his ilk and it is apparent that ideas can be legion.

[1] Published by permission of the author and *Product Engineering* in which it was originally presented in volume 11, on pages 511–512, of the November, 1940, issue.

Ideas are the impingement of imagination on experience. As such there is nothing mysterious or exclusive about their origin and there is no reason why anybody should not have them. They are likely to be original with one person to the extent that his experience or imagination is in advance of that of others. But ideas are the property of no man and are as free as air to those who would seek them.

What does distinguish some ideas from others is the directness and simplicity with which they reach their objective. The question is not "How can an objective be reached?", but rather, "How can it best be reached?" This point of view very evidently strips ideas of any inherent value. They retain value only as they are useful. By the same token, no particular credit redounds to the person who has an idea. Credit is due only to him who has a good idea.

There is no mental quality that permits anyone intuitively to select good ideas and only good ideas. Therefore, the problem of arriving at good ideas is one of elimination. This involves, in the first place, marshaling all of the ideas which can be conjured up on the subject. There is no reason why this procedure should not be orderly. After a little experience the ideas can be classified and all of the permutations and combinations exposed to view. The second step is to submit the various ideas to critical analysis.

Of the two steps, the second is the more difficult. One must be sure on the one hand that no hidden possibility is passed over lightly, and on the other hand that time is not wasted exploring unprofitable alleys of ideas. The quantitative attitude of approach toward this analysis is most valuable as it will eliminate the great mass of ideas which are qualitatively practical but quantitatively impractical.

An attitude which must be repelled is the proprietary one. It makes an idea no better just because I happen to have thought of it rather than you. It must derive its value without respect to who conceived it. Since the value of ideas can be proved by practice, it behooves each individual to see that his ideas are used only when they are superior to the ideas of others. There is always a suspicion that a person may not take an objective point of view in comparing his ideas with those of others. For this reason, it is frequently wise to get the opinion of some competent, disinterested person.

It frequently happens that an idea has to be presented in the proper form, that is, "sold" to the person with the necessary authority. It is not fair to suppose that ideas have self-evident merit which should immediately impress a superior, even when he is very receptive. On the other hand, it is important that the idea not be misrepresented.

## Novelty

At first thought it might seem that a new design must have a great deal of novelty to be really valuable or worth while. The new, the miraculously different seems to be the thing which makes the headlines and

attracts the attention. Yet how many times is the article which is radically different from all competitors the sales leader? Not many. True, when the advantages are clear and self-evident, then sales may flow to the novel product. But it lacks the mutual sales help of competitors which are much alike. A good example of this is the steam automobile. Basically a much simpler and more flexible machine than the conventional type, its patent protection and uniqueness proved its undoing.

Look around and consider how many things of a mechanical character which are considered indispensable represent the simplest, most dramatic approach to the problem. Then consider the vastly larger number of things which are the fruit of years of polishing what may basically be a very impractical idea. The automobile is perhaps the perfect example of this. Rube Goldberg himself could hardly have conceived of the automobile transmission, clutch, or ignition system. Before the automobile of today could be perfected it was necessary to establish and develop whole new industries, such as that of alloy steels. Every important part is the result of years of effort to achieve the best possible result without any fundamental change which would affect too many other parts.

Most progress in the line of machines comes as a gradual evolution of an existing type. There comes a time, however, when a radical departure must be made from previous forms if further progress is to be made. The new type is usually the survival of a whole series which have been tried and discarded. Naturally this process is expensive and is usually left to the little fellows who do not have much of a stake to lose. On the other hand, it pays every company to keep informed of progress and trends and occasionally to make a "scoop" by bringing out an advanced design.

*Harris and Ewing*

People thought both of these ideas were ridiculous, but the one above was sublime. Knowing when not to laugh an idea out of existence calls for acute foresight and sound engineering judgment.

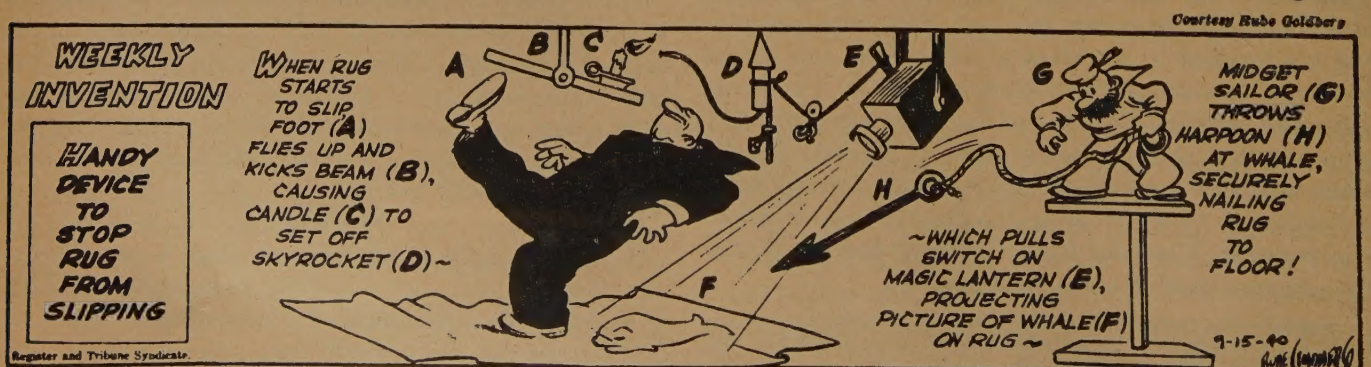
What philosophical attitude can we have toward novelty? First, we can stop chasing will-o'-the-wisps; we can look to the present forms and study them to see how they can be made more perfect; we can accept something which may never reach the heights of ultimate perfection and refine it in detail to make it a highly workable design. Second, we must keep before us the ideal of a design which will not have the inherent limitations of the present type; we can and must be dissatisfied with present forms, striving for a simpler and basically better form. Third, we must appreciate the problems inherent in the attainment of the simpler form; the long search, the slow perfection to a usable state, the breaking down of commercial and psychological barriers to its use.

## Selling the Idea

Equipment design and selling would seem to be as far apart as the poles. Nevertheless, there are times when the development man can serve his company best if he has the ability to "sell" his ideas to his superiors. It is a common belief that new ideas originate in the sales force in the field from whence they flow back to the development department, which puts them into workable form. Actually, this is seldom the case. The salesman must take a somewhat uncritical attitude toward the equipment which he sells in order to maintain his selling integrity. Naturally, he glosses over imperfections as long as possible.

On the other hand, the imaginative designer is painfully aware of the deficiencies of his design, even though he is not permitted to give voice to them publicly. More than that, he visions a product not only better in detail, but in basic conception as well.

The engineer need not take the role of the partisan in his presentation. His job is to show the relation of his ideas to others which might be considered. He should assume the attitude of an advocate only long enough to obtain recognition for his ideas, then he should revert to the judicial point of view. Often it is better to unfold the picture gradually, over a period of time, through the


Courtesy Rube Goldberg
WEEKLY INVENTION
HANDY DEVICE TO STOP RUG FROM SLIPPING
WHEN RUG STARTS TO SLIP FOOT (A) FLIES UP AND KICKS BEAM (B), CAUSING CANDLE (C) TO SET OFF SKYROCKET (D)~
~WHICH PULLS SWITCH ON MAGIC LANTERN (E), PROJECTING PICTURE OF WHALE (F) ON RUG ~
MIDGET SAILOR (G) THROWS HARPOON (H) AT WHALE, SECURELY NAILING RUG TO FLOOR!
A
B
C
D
E
F
G
H
9-15-40
Register and Tribune Syndicate.

medium of periodic suggestions. It frequently takes time to change mental patterns to meet new suggestions. But by means direct or devious, the engineer must somehow present the picture of the future in compelling terms.

### Ideas and Organization

A development program must be organized in one of two ways; either one man or group must carry it through from beginning to end, or it must be passed successively from one specialized group to the next until it is finally completed.

For one man to carry on a project from beginning to end with success requires a most rare combination of abilities. It is an axiom that no man is at once a good beginner and a good finisher. To launch a development needs a man of boundless imagination. He should be able to think of all of the ways under the sun of doing a thing. His mind should range through all the possible and impossible ideas for accomplishing the desired end. Sometimes he will be able to distinguish between the possible and the practical. Often this must be done by someone with his feet more firmly on the ground. But even the "crackpot" inventor has his place at the beginning of a development.

Once the development passes its initial phases, however, this type of man usually loses interest. In his imagination it is already complete and perfect and his interest seeks out still other ideas. Such a man has not the patience to guide the development through its slow perfecting stages.

Here is needed a "hound" for detail, who can take all of the "kinks" out of the design, who can sharpen his pencil and whittle first dollars and then pennies out of the cost. He must be willing to prove the practicability of each part and of the whole design by exhaustive laboratory tests and field trials. Frequently, before the development is turned out as complete, quite a number of people must each take a hand in it in succession. More often than not the tooling and the introduction to manufacture is handled separately.

When one man is in a dominant position with respect to a development, he leaves the stamp of his personality upon the design. His weaknesses may be as evident as his strong points. Why then should carrying on the development under one man be considered? Because the other alternative is equally dangerous. When a design is passed on to a new group, something is lost in the transfer. Frequently the new group may approach the design from an entirely new point of view and lose much that was of value in the original design. The people dominating each step are likely to have their own pet ideas, which may find their way into the finished product to its detriment.

It is evident that there is no "royal road." Regardless of the method of organization, the project must depend for success upon the ability of the people who are to carry it on. Also, there must be no insulation, no barriers between the men or groups carrying on the development; each must be subjected to the same ideas and the same criticisms. This naturally indicates that there must be a common leader throughout the progress of the design.

How, then, are the disadvantages of this type of organization to be overcome? Most important of all, the leader must understand himself. He must know where his strength lies and where his weakness; where he can rely largely on his own judgment and where he must call on that of others. He must gather around him men who will complement his abilities in order to form a well-rounded group. He must know when to call for help outside of his group. Furthermore, this leader, by understanding his point of weakness, can gradually train himself to a rounded ability more nearly approaching that of the ideal development man. He can also learn a tolerance for diverse points of view which can contribute to the success of the development and can learn to accept even though he cannot sympathize with them.

There are, of course, many able men who, because of a too great one-sidedness or because of an insulation from the point of view of others, can never become leaders.

The administrator to whom the leader reports must provide a point of view which balances that of the leader. He must also see that the leader is surrounded by adequately complementary assistants. Thus, one of the most important aspects of the organization of development work is to study and train the aptitudes of individuals in order to fit them together into harmonious and well-rounded groups capable of carrying through a development from rough idea to finished product.

## Correction

H. T. Friis, whose paper "Noise figures of radio receivers," appeared in the July, 1944, issue of the Proceedings on pages 419–423, has brought to the attention of the Editor an error in equation (15).

The formula appears as follows:

$$F_{ab} = (F_a + F_b) - 1/G_a. \qquad (15)$$

The corrected formula is

$$F_{ab} = F_a + (F_b - 1)/G_a. \qquad (15)$$

# A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver*

G. L. BEERS†, SENIOR MEMBER, I.R.E.

*Summary*—**A new type of frequency-modulation receiving system is described in which a continuously operating local oscillator is frequency-modulated by the received signal. In an embodiment of the system which is described, the oscillator is locked in with the received signal at one fifth the intermediate frequency. With this 5:1 relationship between the intermediate frequency and the oscillator frequency, an equivalent reduction in the frequency variations of the local oscillator is obtained. Received signal-frequency variations of ±75 kilocycles are reproduced as ±15-kilocycle variations in the oscillator frequency. The frequency-modulated signal derived from the oscillator is applied to a discriminator which is designed for this reduced range of frequencies.**

**The oscillator is designed to lock in only with frequency variations which occur within the desired-signal channel. The oscillator is, therefore, prevented from following the frequency variations of a signal on an adjacent channel. A substantial improvement in selectivity is thus obtained.**

**The voltage required to lock in the oscillator with a weak signal is approximately one twentieth of the voltage applied to the discriminator. Since this voltage gain is obtained at a different and lower frequency than the intermediate frequency, the stability of the receiver from the standpoint of over-all feedback is materially improved.**

**Other performance advantages and the factors affecting the operation of the sytem are discussed.**

FREQUENCY-modulation broadcasting is still in its infancy in terms of a nation-wide entertainment service. Until a large number of high-powered frequency-modulation broadcast stations are operating on a commercial basis, the major technical problems which are involved in the design of frequency-modulation receivers will not be fully appreciated. However, the experience which has already been gained from frequency-modulation broadcasting has indicated some of the problems which must be given serious consideration.

Probably the most difficult requirement to be met is that of obtaining adequate adjacent-channel selectivity. This problem was emphasized by a report on "Blanketing of High-Frequency Broadcast Stations" issued in 1941 by the Federal Communications Commission. High sensitivity is necessary in a frequency-modulation receiver to insure maximum performance. This requirement makes it difficult to provide the desired over-all stability without excessive shielding and other circuit complications. This problem has already been the subject of a great deal of engineering investigation and one of the solutions which has been proposed is the use of the double heterodyne type of superheterodyne receiver. A new approach to a solution of these problems is provided by a frequency-dividing locked-in oscillator frequency-modulation receiving system which has been developed.[1] It is the purpose of this paper to describe the new receiving system and to indicate some of the factors which affect its operation.

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† Radio Corporation of America, RCA Victor Division, Camden, New Jersey.

## Description of System

Basically the operation of the system depends on producing, in the receiver, a local signal which is frequency-modulated by the received signal. The local signal is provided by a continuously operating oscillator. The received signal, after it has been amplified by conventional radio-frequency and intermediate-frequency amplifiers, is applied to the oscillator in such a way as to cause its frequency to change in accordance with the frequency variations of the received signal. In the particular applications of the system to be described in this paper, the oscillator is locked in with the received signal at one fifth the intermediate frequency. With this 5:1 relationship between the intermediate frequency and the oscillator frequency an equivalent reduction in the frequency variations of the local oscillator is obtained. Received-signal frequency variations of ±75 kilocycles are reproduced as ±15-kilocycle variations in the oscillator frequency. It should be noted that the locked-in oscillator operating at one fifth the intermediate frequency reduces the frequency deviation corresponding to any modulation frequency but does not change the modulation frequency. The frequency-modulated signal derived from the oscillator is applied to a discriminator which is designed for this reduced range of frequencies.

The output voltage of the oscillator is independent of the strength of a received signal, in fact, the same voltage is applied to the discriminator when no signal is being received as when the receiver is tuned to a near-by transmitter. This feature makes it unnecessary to employ the conventional arrangements for minimizing amplitude variations in the received signal.

The adjacent-channel selectivity of a conventional frequency-modulation receiver is determined by the selectivity characteristics of the radio-frequency and intermediate-frequency circuits. If these circuits do not provide sufficient selectivity, a local transmitter on a channel adjacent to the desired signal may produce, at the discriminator, a substantially greater voltage than is obtained from the desired station. Under these conditions the desired program will not be heard. In the new receiving system a novel principle is used to provide

[1] United States Patent No. 2,356,201, filed February 12, 1942.

additional adjacent-channel selectivity. The oscillator is designed to "lock in" only with frequency variations which occur within the desired-signal channel. The oscillator is therefore prevented from following the frequency variations of a signal on an adjacent channel. A substantial improvement in selectivity is thus obtained by electronic means.

The "locked-in" oscillator arrangement which is used provides, under weak signal conditions, a voltage step up of approximately 20. In other words, the voltage required to lock in the oscillator with a weak signal is approximately one twentieth of the voltage applied to the discriminator. Since this voltage gain is obtained at a lower frequency than the intermediate-frequency, the stability of the receiver from the standpoint of over-all feedback is materially improved. This improvement is secured without the disadvantage of the additional image responses which are obtained with the double-heterodyne type of superheterodyne receiver.

One receiver arrangement is shown in Fig. 1. In this diagram the units which are heavily outlined are those which are peculiar to the new system.

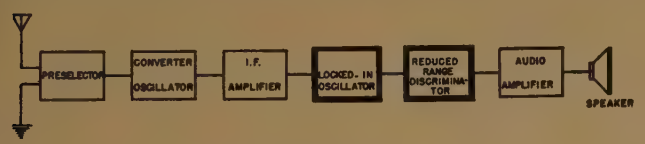


Fig. 1—Block diagram.

## Description of the Locked-In Oscillator

The locked-in oscillator circuit diagram is shown in Fig. 2. The tube generally used in this circuit has been an A-5581, an experimental converter tube, which is similar to the 6SA7 but has a higher mutual conductance. The oscillator tuned circuit is connected to the plate of the tube and the feedback coil is connected to

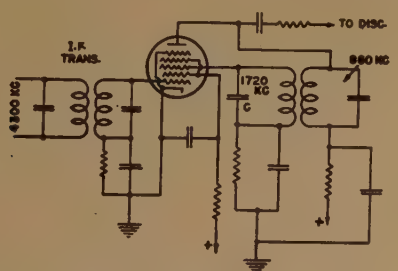


Fig. 2—The locked-in oscillator.

the No. 3 grid. This grid is operated with self-bias. The received signal is applied to the No. 1 grid of the tube through a 4300-kilocycle intermediate-frequency transformer. The No. 1 grid is likewise operated with self-bias.

## Description of Discriminator

One type of discriminator that can be used with the locked-in oscillator is shown in Fig. 3. This circuit has a pair of diodes connected with their load resistors in opposition so the discriminator is balanced at the center frequency. One diode has a tuned circuit in series with it and the other has a tuned circuit across it. The discriminator is connected across the tank circuit of the locked-in oscillator through the coupling capacitor shown in the diagram. The audio-frequency output from the discriminator is fed through a de-emphasis network to the audio amplifier.

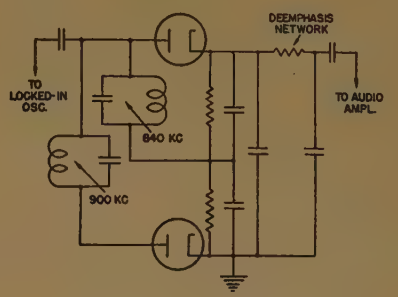


Fig. 3—Discriminator.

## Why the Oscillator Locks In with the Received Signal

Theoretical and experimental evidence indicates that the locked-in oscillator circuit operates in accordance with the following theory.

As previously stated, the oscillator is designed to lock in at one fifth the intermediate frequency. With an intermediate frequency of 4300 kilocycles the oscillator tank circuit is tuned to 860 kilocycles. When no signal is being received the tube will function as a normal oscillator. The amplitude of the oscillation in a feedback oscillator is determined by the curvature of the $E_g - I_p$ characteristic and is usually so great that the grid voltage swings well into the curved parts of the tube characteristic during the cycle. This means that a distorted output current is produced in the plate circuit, having component frequencies $2\omega$, $3\omega$, $4\omega$, $\cdots$ where $\omega$ is the natural frequency of the tuned plate circuit. These harmonics are applied to the No. 3 grid because of the regenerative coupling. Furthermore, the No. 3 grid operates with self-bias and draws grid current during the positive swings of voltage. The grid-current pulses also contain the harmonics of $\omega$.

Suppose now that the signal voltage of frequency $5\omega$ (4300 kilocycles) is applied to the No. 1 grid. Since the tube is a nonlinear device and operates as a converter, combination frequencies will be produced equal to $\pm 5r\omega \pm s\omega$ where $r$, $s = 0, 1, 2, 3, \cdots$. Since the plate circuit is tuned to a frequency $\omega$ (860 kilocycles), the only frequencies which will be amplified are those of frequency $\omega$; the others will be by-passed effectively. If $r = 1$, then $s = 4$ or 6 will give the frequency $\omega$. This means that either the fourth or the sixth harmonics of the oscillator will beat with the incoming signal, having the frequency $5\omega$, to give the frequency $\omega$.

This added 860-kilocycle component of the plate current caused by the harmonics of the oscillator beating with the incoming signal is in phase with the 860-kilocycle current in the oscillating plate circuit. The circuit

becomes stable in this condition and the injected current will "lock in" the incoming 4300-kilocycle signal with the 860-kilocycle current in the plate circuit. Since the injected current has the same phase and frequency as the normal current, it is merely equivalent to an increased output from the tube.

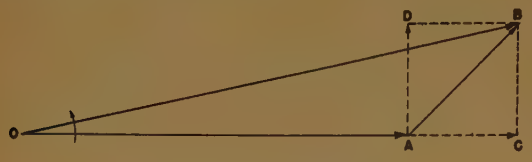


Fig. 4—Vector diagram.

Now suppose that the frequency of the incoming signal is increased somewhat. The effect of the fourth harmonic will be to inject a current of slightly greater frequency than 860 kilocycles into the tank circuit. The sixth harmonic will also cause an injected current of slightly less than 860 kilocycles; this will be considered later. Assume for the moment that the oscillator is *not* locked in. In Fig. 4, $OA$ is a vector rotating 860,000 times per second and represents the normal current in the oscillating tank circuit. Let $AB$ be the injected current of frequency slightly greater than 860 kilocycles, from the fourth harmonic of the oscillator voltage beating with the incoming signal voltage. This vector will rotate slightly faster than 860,000 times per second and thus will have an angular velocity relative to $OA$ equal to the difference of the two angular velocities.

Now consider the instantaneous condition shown in Fig. 4. The injected current $AB$ has a component $AC$ in phase with $OA$ and another component $AD$, 90 degrees out of phase with respect to $OA$. Let this resultant current $OB$ be applied to a tuned circuit $LC$ as shown in Fig. 5. Since the $LC$ circuit is tuned to 860 kilocycles, it will be at resonance with respect to the current $OC$ which is also 860 kilocycles and equals $i_a+i_b$. The quadrature current $AD$ is a leading current at the instant shown by Fig. 4, and the result is the same as though an additional condenser $C'$ is in the circuit. The effect is to *decrease* the natural frequency of the tuned circuit.

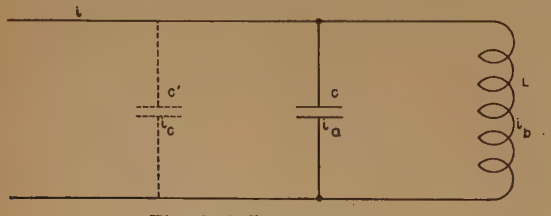


Fig. 5—Effect on circuit.

Now consider the condition at a later instant as shown by Fig. 6. Since the vector $AB$ is rotating with respect to $OA$ it has now rotated to the new position as shown. The injected current $AB$ now has an in-phase component $AC$ as before, but the component $AD$ is now lagging instead of leading. If this current $OB$ is now impressed on the circuit of Fig. 5, the lagging component $AD$ will cancel part of the leading current through $C$ and this will be equivalent to reducing the capacitance $C$ since the circuit is now drawing a smaller leading current. This will raise the resonant frequency of the tuned circuit.

It is now evident that the circuit of Fig. 2 behaves like a reactance tube and swings the frequency of the tuned circuit back and forth. It is easy to see that if the frequency of the incoming signal is approximately five times that of the tuned circuit, a point will be reached when the frequency of the tuned circuit becomes exactly one fifth of the incoming signal frequency. When this happens the oscillator will "lock in" with the incoming signal. This means that the amplitude and phase of the plate current now remain fixed with respect to the incoming signal; vector $AB$ now makes a constant angle $CAB$ with $OA$.

If the incoming signal is exactly five times the frequency of the tuned-plate circuit, the vector $AB$ will be in phase with $OA$. As the incoming signal frequency is decreased, the vector $AB$ rotates to some position such as that shown in Fig. 4. A further decrease in frequency will rotate the vector until it is 90 degrees out

Fig. 6—Vector diagram.

of phase with respect to $OA$. Since this position gives the maximum amount of quadrature current it corresponds to the maximum amount the oscillator frequency can be pulled over, and thus gives the lower limit of the lock-in range.

If the incoming-signal frequency becomes greater than five times the plate-circuit frequency, the conditions will be similar except that the vector $AB$ will be lagging as shown by Fig. 6 instead of leading. The upper limit of the lock-in range is reached when the injected current lags by 90 degrees. The lagging current tends to reduce the effective capacitance of the circuit and thus raises the frequency.

When the sixth and fourth harmonics are both present simultaneously, it can be shown that the result is a single injected current of variable amplitude and phase. This causes the frequency of the tuned circuit to swing back and forth in accordance with these variations; the process is very similar to that already explained when the fourth harmonic only is present. Usually, the fourth and sixth harmonics will be of unequal amplitude and the effect of the weaker one is to produce relatively small variations in the other.

## Lock-In Range Requirements

As previously stated by restricting the lock-in range of the oscillator to frequency variations in the desired

channel a material improvement in selectivity can be obtained. On the other hand, it is necessary that the lock-in range be adequate to follow the frequency variations of the received signal and in addition provide for

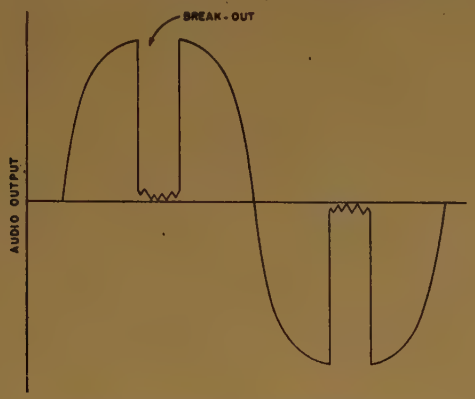


Fig. 7—Breakout characteristic.

receiver mistuning and frequency drift in the transmitter and receiver.

The effect of the fourth and sixth harmonics in controlling the lock-in range of the oscillator has been previously discussed. The amount of fourth and sixth harmonics on the No. 3 grid of the oscillator is limited, and this limits the lock-in range. When the deviation exceeds the lock-in range the oscillator breaks out and starts back toward the center frequency since it is no longer controlled. The oscillator may then suddenly jump to a series of different frequency ratios such as, · · · 36/7, 41/8, 46/9 · · · 5/1, · · · , 44/9, 39/8, 34/7, · · · for short intervals. The lock-in range for each of those ratios is very small, and the oscillator breaks out between them. The result can be a distorted output as shown by Figs. 7 or 8. It is, therefore, necessary to provide adequate lock-in range in order to prevent this distortion.

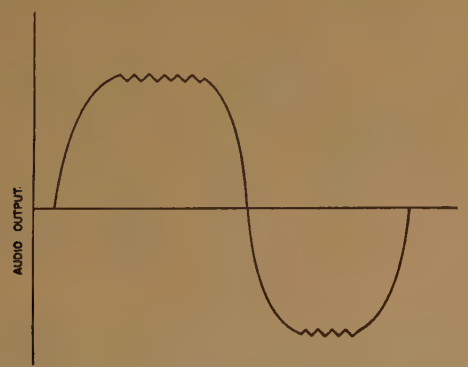


Fig. 8—Breakout characteristic.

## Factors Which Determine The Lock-in Range

The lock-in range of the oscillator depends upon several factors which will now be discussed.

### *Effect of Discriminator*

When a discriminator is connected to the oscillator, it changes the impedance relations of the tank circuit and increases the lock-in range. The equivalent input capacitance of the discriminator circuit shown in Fig. 3 decreases rapidly with frequency near the center frequency of the oscillator. Fig. 9 shows how this capacitance falls off near the center frequency $f_0$. If the oscillator

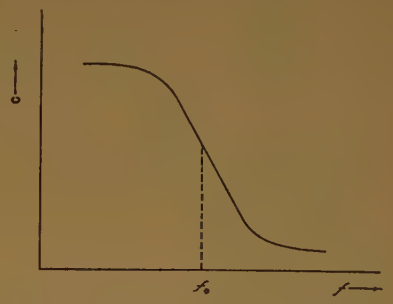


Fig. 9—Input capacitance of discriminator.

tank circuit is to be kept in tune over the operating frequency range, the tank circuit capacitance should decrease with increasing frequency as shown by Fig. 10. The slope of this curve is determined by the $L/C$ ratio of the tank circuit.

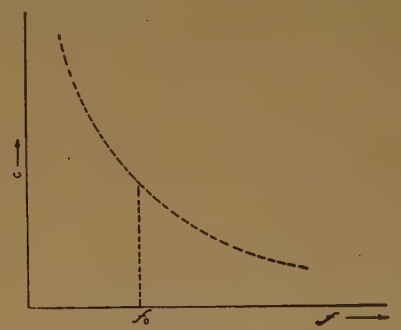


Fig. 10—Oscillator-tuning capacitance.

The discriminator input capacitance characteristic can be designed to provide an apparent capacitance change with frequency nearly to match the requirements for tuning the oscillator.

In Fig. 11 the solid line represents the falling input capacitance of the discriminator and the dashed line is

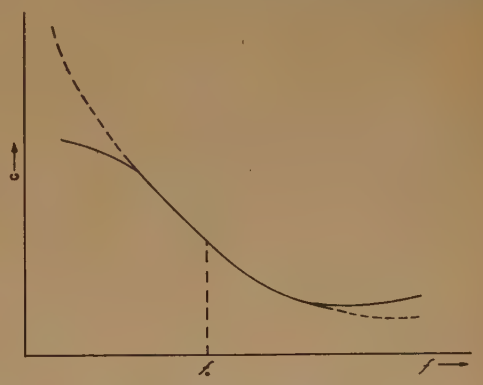


Fig. 11—Matching the discriminator to the oscillator.

the variation of capacitance required to keep the oscillator in tune as the frequency is varied. If the two curves have approximately the same slope at the center frequency $f_0$, the lock-in range will be greatly increased since only a small amount of reactive current will shift the oscillator frequency a considerable amount.

*Effect of Signal Voltage*

If the No. 1 grid is operated with self-bias so that the operating bias is approximately equal to the peak amplitude of the applied signal voltage, the lock-in range will be as shown by Fig. 12.

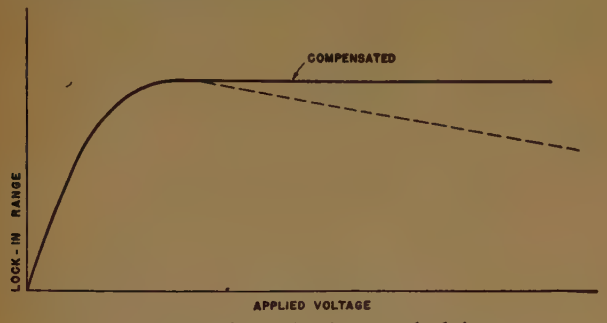


Fig. 12—Effect of signal voltage on lock-in range.

For small applied voltages the lock-in range increases rapidly from zero with increasing signal voltage until it reaches a maximum, and it then decreases slowly with further increase in voltage as shown by the dashed line.

In practice, the screen and plate resistors can be chosen to correct this falling off of the lock-in range with increased input. This compensation will give the constant lock-in range beyond the knee of the curve as shown by the solid line.

*Effect of Tube Constants*

The lock in range depends upon the amount of quadrature current that can be developed by the tube. This means that the tube should have a fairly high zero-bias plate current and a fairly high mutual conductance from the No. 1 grid to plate. This assures large pulses of plate current which produce the required reactive current. The experimental A-5581 tube has been found to meet these requirements. This tube is similar to the 6SA7 but provides increased peak current and increased mutual conductance.

*Effect of Intermediate-Frequency Selectivity on Lock-In Range*

The primary effect of intermediate-frequency selectivity is to attenuate the voltage on the No. 1 grid as the signal frequency moves down the side of the selectivity curve. Naturally the oscillator cannot lock in if the incoming signal voltage becomes too small. This means that the bandwidth of the intermediate-frequency amplifier will affect the lock-in range. Fig. 12 shows the variation of lock-in range with input voltage. The range falls off very rapidly when the applied voltage falls below the knee of the curve. The amplifier should be designed so it is broad enough to assure sufficient voltage to lock in the oscillator at the maximum frequency swings encountered and also to provide for drift and mistuning.

*Effect of Oscillator Frequency*

The lock-in range is in general inversely proportional to the oscillator tank circuit $C$. An increase in the intermediate frequency will result in an increase in the lock-in range only when $C$ is correspondingly reduced.

*Effect of Feedback Winding*

The lock-in range will increase somewhat with increased mutual inductance from the tank coil to the feedback winding. Fairly tight coupling should be used for increased range.

A method which can be used to increase the lock-in range is to tune the feedback winding to the second harmonic of the oscillator as shown by Fig. 13. Capacitor $C$ is chosen to tune the grid circuit to 1720 kilocycles. This builds up the second harmonic, which in turn causes an increase in the fourth and sixth harmonics because of the nonlinearity of the tube. The result is an increase in the lock-in range.

## Noise-Reduction Characteristics

It has been previously stated that the locked-in oscillator arrangement can be designed to increase materially the adjacent-channel selectivity of a receiver. This improvement is obtained by restricting the lock-in range of the oscillator so that it will follow only the frequency variations which occur within the desired channel. This restricted lock-in range is of interest also from the standpoint of the noise-reducing properties of the receiver.

In conventional frequency-modulation receivers the discriminator is designed so that the linear portion of its response characteristic is adequate to accommodate the frequency variations of received signals, with due allowance for mistuning both by the user and that resulting from frequency drift of the heterodyne oscillator. The curved portions of the discriminator characteristic which extend beyond the linear region just referred to provide an additional frequency range in which noise components with wide frequency variations are converted into amplitude variations. Fig. 14 shows a typical discriminator characteristic in which $AB$ is the linear region within which the frequency variations of received signals are converted into amplitude variations. The sections of the characteristic designated $CA$ and $BD$ are the portions which are not useful in the reception of desired signals because of the curvature, but which are effective in converting frequency-modulation noise components into amplitude variations. The upper figures, indicating deviation, correspond to the discriminator characteristic in a conventional receiver, while the lower figures

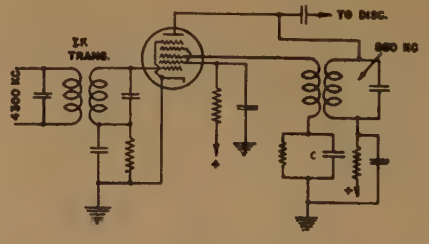


Fig. 13—Tuned-feedback coil.

are the frequency values for the locked-in oscillator discriminator. The restricted frequency range of the oscillator in the locked-in oscillator type of receiver can be used to limit the portion of the discriminator characteristic, which is utilized in converting the frequency variations of both the received signal and noise components into amplitude variations, to the linear region $AB$.

Another characteristic of the locked-in oscillator which may be used to advantage in minimizing the effects of noise is the ability to prevent the oscillator from following the frequency variations corresponding to superaudible noise components. This is accomplished in the oscillator arrangement shown in Fig. 2 by the proper choice of circuit constants.

## Modified-Circuit Arrangement

A modification of the frequency-dividing frequency-modulation receiver has been developed by which its ability to select between desired signals and undesired signals or noise is further extended. Fig. 15 is a block diagram of this modification.

The locked-in oscillator used in this arrangement is likewise designed to operate at one fifth of the intermediate frequency. The normal lock-in range of the oscillator, however, is restricted to only 20 to 35 per cent of the frequency-variation range required for received signals. This very restricted lock-in range is extended by means of a reactance-tube arrangement so that the oscillator will follow the maximum frequency variations of received signals. The audio-frequency potential developed at the discriminator-rectifier combination is applied through a phase-correcting network to the reactance tube in the proper phase and magnitude to cause the reactance tube to shift the oscillator resonant frequency so that at any instant its frequency is such that the limited lock-in range will permit it to lock in with

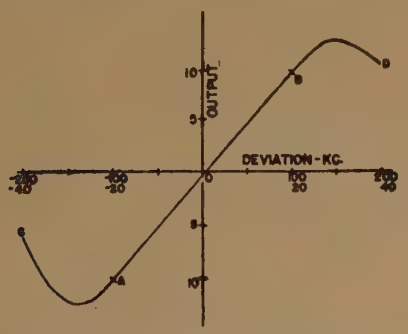


Fig. 14—Discriminator characteristic.

the received signal. The amplitude of the control potential applied to the reactance tube is normally kept slightly below the value which would shift the oscillator to the correct frequency, assuming that the oscillator had no lock-in range. In other words, for 100 per cent modulation the reactance tube shifts the oscillator frequency by slightly less than $\pm 15$ kilocycles.

Let us consider the merits of this arrangement in connection with noise impulses and adjacent-channel selectivity. Superaudible frequency-modulation noise components applied to the input circuit of the locked-in oscillator may appear in the oscillator output circuit. The phase-correcting network, however, may be designed so that these components either are not fed back to the reactance tube at all or are not fed back in such phase and amplitude as to permit the oscillator to follow them. In other words, the receiving system is provided

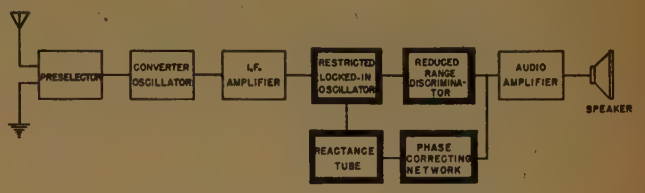


Fig. 15—Modified-circuit arrangement.

with a circuit which is responsive only to small frequency variations and this restricted-response range is moved back and forth at a rate which follows the desired modulation of received signals but is not moved back and forth at a rate which will follow superaudible noise impulses which may be present with the received signals.

The effect of the reactance-tube arrangement on adjacent-channel selectivity is also of interest. This can best be understood by reference to the discriminator-rectifier—voltage-frequency response characteristic shown in Fig. 14. As the output potential of the discriminator-rectifier and hence the potential applied to the reactance tube varies over the useful portion of the discriminator characteristic (the linear portion of the characteristic between the points $A$ and $B$) the effect of the reactance tube is to shift the oscillator frequency in the same direction as the frequency changes which give rise to the demodulator potentials. If, on the other hand, we assume that a signal on the adjacent channel could reach the discriminator circuits and produce potentials caused by frequency variations over the side of the discriminator characteristic as indicated by the portion $A$–$C$ of the curve, the phase of the potentials applied to the reactance tube would be such that the effect of the reactance tube on the oscillator would be to reverse the direction of the oscillator-frequency change. That is, the reactance tube cannot shift the oscillator frequency so that it will lock in with the signal on an adjacent channel because the circuit elements are so designed that if the frequency of the oscillator were to change beyond the useful range of the discriminator and towards the adjacent channel, the phase and magnitude of the potential applied to the reactance tube would shift in such a manner that the oscillator frequency would be shifted away from the adjacent channel frequencies.

## Experimental Results

As a part of an experimental investigation of the new receiving system, work was carried on with two identical commercial receivers. One was modified by incorporating the locked-in oscillator and reduced-range discriminator, shown in Fig. 16, in place of the two-tube cascade limiter and the discriminator used in the original

construction. The other receiver was used for comparative tests in the laboratory and field. This procedure was repeated with two identical laboratory receivers constructed along conventional lines.

It should be noted that the locked-in oscillator circuit shown in Fig. 16 is representative of the receiving system illustrated by the block diagram in Fig. 1. This arrangement was used in preference to the modification illustrated by the block diagram in Fig. 15 because it was less complicated and, therefore, considered more suitable for commercial receivers.

With the arrangement shown in Fig. 16 an intermediate-frequency signal of about 1 volt on the No. 1 grid of the oscillator tube was required to provide the desired lock-in range of approximately ±110 kilocycles. The frequency range in excess of the ±75 kilocycles required for the normal modulation of a received signal is provided to take care of mistuning by the user, frequency drift of the heterodyne oscillator, and overmodulation at the transmitter. The oscillator voltage developed at the discriminator was between 20 and 30 volts. From the foregoing, it is apparent that the receiver should be sufficiently sensitive to produce 1 volt on the No. 1 grid of the oscillator to provide satisfactory reception of a desired signal.

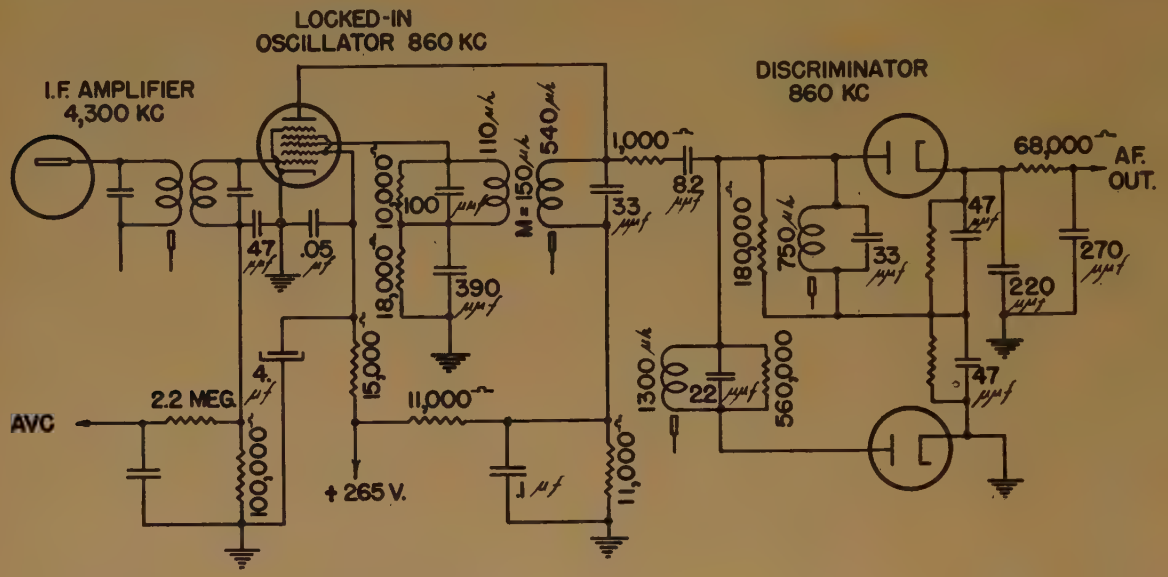


Fig. 16—Locked-in oscillator and discriminator.

*Improvement in Selectivity*

The results of selectivity measurements, made by the two-signal method, are shown in Fig. 17. In these tests, the receivers were tuned to a desired signal of 100 microvolts, with 400-cycle modulation and a deviation of ±25 kilocycles. An interfering signal, modulated with 1000 cycles, and a deviation of ±25 kilocycles, was adjusted in signal strength and frequency to give an interference output 30 decibels below the 400-cycle output. A considerable improvement in selectivity, especially for the entire adjacent channel, is shown with the receiver employing the frequency-dividing locked-in oscillator system. It should be noted that with an increase in interfering signal, a point of oscillator breakout may always be reached. The level of interfering signal at which breakout occurs is higher than the −30-decibel interference level. The improvement in adjacent-channel selectivity, shown by these curves, is equivalent to the addition of two intermediate-frequency stages in the receiver.

*Impulse Noise Interference*

Oscilloscopic investigations of the effects of impulse interference with both modulated and unmodulated signals were made with the four receivers. The results indicated a general superiority in noise reduction for the frequency-dividing locked-in oscillator system.

*Field Tests*

Field tests showed the receivers using the new receiving system to be considerably more selective with respect to adjacent-channel interference than conventional commercial receivers. More distortion was, however, encountered when the locked-in oscillator receivers were tuned so that the signal was received at the edges of the receiver-response characteristic than was obtained with the conventional units. This is due to the oscillator breakout characteristic and the fact that the voltage at the discriminator remains fixed irrespective of the signal applied to the oscillator. In general, it can be stated that an increase in distortion, when tuned to one side of a desired signal, goes hand in hand with increased adjacent-channel selectivity in any type of radio receiver. Some observers felt that this effect assisted in properly tuning the receiver.

Observations with respect to noise reduction substantiated the laboratory measurements which previously have been discussed.

*Modified-Circuit Arrangement*

An experimental receiver was also constructed incorporating the modified arrangement illustrated by Fig. 15. Although the tests on this receiver were not so extensive as those on the receivers in which the Fig. 16

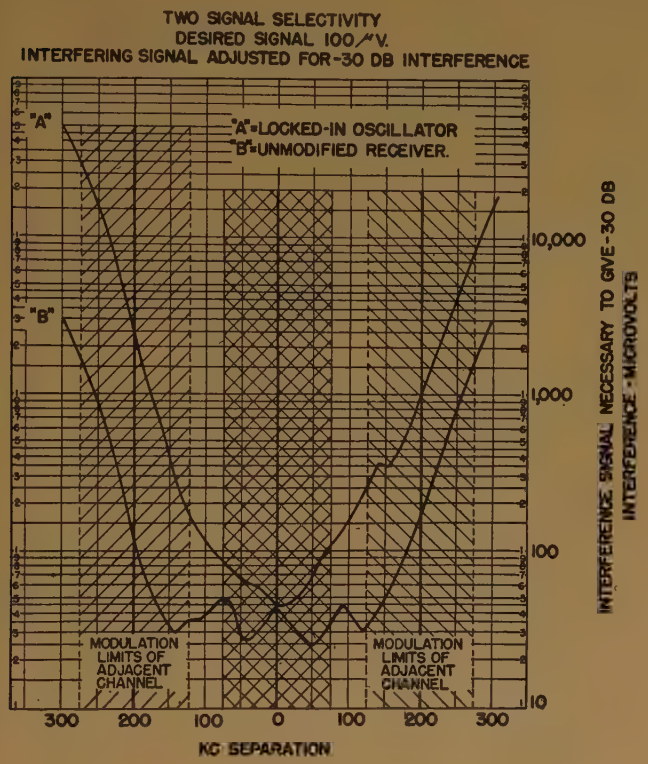


Fig. 17—Selectivity curves.

arrangement was used, they did indicate that the modified circuit possessed superior noise reducing and adjacent-channel selectivity characteristics.

## Conclusions

A novel method of receiving frequency-modulated signals has been investigated both theoretically and experimentally. The investigation indicates that the system has the following advantages:

1. By restricting the lock-in range of the oscillator to follow only the frequency variations which occur within the desired-signal channel, a material improvement in selectivity is obtained.
2. An equivalent voltage step-up is secured at a different and lower frequency than the intermediate-frequency and a corresponding improvement in freedom from over-all feedback is secured.
3. A constant voltage is applied to the discriminator irrespective of the strength of a received signal, and arrangements for minimizing amplitude variations in a received signal are, therefore, not required.
4. The frequency-dividing locked-in oscillator receiving system provides a means for incorporating, in a frequency-modulation receiver, a type of selectivity which can be used to discriminate between the desired-signal modulation and frequency-modulation-noise components.

The following characteristics should also be considered in an evaluation of the system:

1. Adequate receiver gain ahead of the locked-in oscillator must be provided if distortion of the weaker signals (due to the oscillator falling out of step), is to be prevented.
2. When the receiver is tuned through a signal, more noticeable distortion occurs at the edges of the receiver response characteristic than is obtained with a corresponding conventional receiver.

## Acknowledgment

The writer wishes to acknowledge the valuable assistance of Messrs. M. S. Corrington, G. L. Grundmann, W. R. Koch, and W. F. Sands during the development of the frequency-dividing locked-in oscillator frequency-modulation receiver.

# Electronic Apparatus for Recording and Measuring Electrical Potentials in Nerve and Muscle*

WILLIAM M. ROGERS†, NONMEMBER, I.R.E., AND HORACE O. PARRACK‡, NONMEMBER, I.R.E.

*Summary*—Electronic apparatus used in studying action potentials is described. It consists of:

1. A variable-frequency stimulator with a volume control which governs the intensity of current used for exciting the nerve or muscle.
2. A trigger circuit synchronizing the sweep of the recording system, a cathode-ray oscilloscope with the stimulator.
3. A recording system, a cathode-ray oscilloscope whose circuit has been altered to permit synchronization with the trigger circuit.
4. A resistance-capacitance-coupled amplifier with one balanced push-pull input stage used as a preamplifier to feed a high-level signal into the differential stage which effectively cancels in-phase signals. This stage is supplied with an input jack permitting its use as the input stage when low-level signals are not encountered. This is followed by three single-ended stages each having an output jack.

A theory of nerve conduction is discussed. The formation of diphasic and monophasic wave forms is described and illustrated. A method for measuring conduction rate is also considered.

ACTIVITY of the nervous system and of muscles is accompanied by changes in electrical potential. These changes are accepted as the electrical signs of activity[1] and are called action potentials. These differences of potential are very small, being of the order of microvolts and millivolts. In a monograph published in 1935, Adrian[2] reviewed the history of electrophysiology. He pointed out that, until recently, advances in this field were limited by lack of sensitive apparatus. With the development of vacuum tubes, apparatus adequate for measuring and recording these minute changes in potential was made available to the physiologist.

Our electronic apparatus for studying bio-electric phenomena consists of

1. A stimulator to excite the nerve or muscle.
2. A trigger circuit to synchronize the horizontal sweep of the cathode-ray oscilloscope with the stimulator.
3. A differential amplifier.
4. A recording system, in our case, a cathode-ray oscilloscope.
5. An extra audio amplifier and recorder with a loudspeaker is not necessary but useful.

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† Department of Anatomy, College of Physicians and Surgeons, Columbia University, New York, N. Y.

‡ Formerly, Department of Physiology, Columbia University; now, Captain, Army of the United States.

[1] J. Erlanger and H. Gasser, "Electrical Signs of Nervous Activity," University of Pennsylvania Press, Philadelphia, Pennsylvania, 1937.

[2] E. D. Adrian, "The Mechanism of Nervous Action," University of Pennsylvania Press, Philadelphia, Pennsylvania, 1935.

The stimulator consists of a master timer and a pulse amplifier (Fig. 1).

It is desirable to have a master timer of variable frequency for controlling the stimulus used to activate a nerve or muscle. A neon bulb pulse generator serves this purpose. The frequency of the stimulus is determined by the combination of condensers and resistors used, and varies inversely with capacitance and resistance.

Directly coupled to the timer is a 6J7 tube ($T_2$) which amplifies the voltage resulting from the condenser discharge. $T_2$, serving as a buffer amplifier, is followed by one or more independent output units. Each output stage is a pentode ($T_3$) operated as class C.

A potentiometer ($P_1$) in the grid circuit of $T_3$ regulates the amplitude of the stimulating pulse. A bank of coupling condensers in the plate circuit permits selection of wave form.

The ungrounded secondary of an output transformer ($Tr_2$) delivers the stimulus to the nerve or muscle. Electrodes applied to the nerve or muscle are of silver wire with silver chloride at the points of contact and insulated everywhere else by rubber lacquer.

## The Trigger Circuit and the Cathode-Ray Oscilloscope

When this stimulator is used to excite a nerve the horizontal sweep of the cathode-ray oscilloscope must be synchronized with the stimulus applied to the nerve. The same neon resistance-capacitance timing unit is used as a trigger circuit. The condenser voltage, amplified by a 6J7 tube ($T_1$), whose output is coupled by a transformer to the external synchronization input terminals of the cathode-ray oscilloscope trips the horizontal sweep. To accomplish this in most 3-inch cathode-ray oscilloscope commercial units, certain changes must be made. An RCA stock unit, No. 155 using a 906-(3-inch) cathode-ray tube was modified in the following way in order to synchronize the timing axis oscillator with the external stimulator.[3]

Two potentiometers ($R100$ and $R101$) were added to the bleeder for the power supply of the cathode-ray oscilloscope unit (Fig. 2A). These potentiometers form a trip-sweep adjustment which increases the difference of potential between grid and cathode of the gas-triode oscillator (884). $R100$ in the grid circuit varies the bias in coarse steps. $R101$ in the cathode circuit varies it in fine steps. Proper adjustment prevents the Thyratron from firing until it is tripped by an impulse delivered to the synchronizing transformer. Both potentiometers are returned to zero resistance for normal

[3] This alteration was suggested by Charles Sheer.

operation. The ground connection from the secondary of the synchronizing transformer must be through *R*100.

The resistance in the plate circuit of the horizontal amplifier was increased (Fig. 2B) in order to increase the gain and allow the spot to be displaced from the fluorescent screen of the cathode-ray tube. The original plate circuit is opened by a switch (*S*5) and the current shunted through the higher resistance (*R*102). The switch is closed for normal operation. The above change in the horizontal amplifier reduces the high-frequency response from about 20 to 5 kilocycles, which is adequate for our needs.

## The Differential Amplifier

High-gain, low-frequency amplifiers are used for amplifying the action potentials in order that they may be recorded. Various circuit arrangements have been published by different investigators during the past ten years.[4–7] These have considered some or all of the difficulties involved in amplifying action potentials. Elimination of interfering electrical fields has been a primary consideration in every design. Interfering voltages, especially in the 60-cycle fields, which may be of the order of tenths or hundredths of volts between each of the input grids and ground, are the chief offenders. These relatively large alternating voltages are approximately in phase at each input electrode while the small desired signal passing along a nerve or muscle is out of phase. The action potential passing along the nerve is out of phase because it arrives at the first grid electrode before it reaches the second. Thus, we may use the difference in conduction time between the two grid electrodes to give an out-of-phase signal.

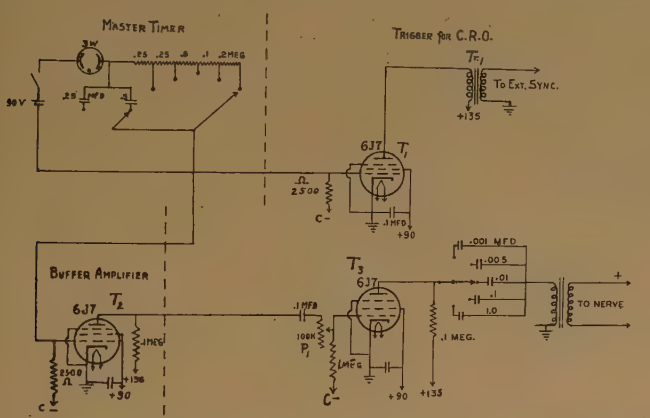


Fig. 1—Circuit diagram of stimulator and trigger circuit for cathode-ray oscilloscope.

## Input Stage

Cancellation of the large undesired in-phase signal may be accomplished by the use of a push-pull amplifier or at least a push-pull input stage. Such an amplifier was designed for multiple recording by Matthews[8] and used successfully by him and Adrian.[2] The electrodes placed at different points along the nerve are connected to grids of two matched tubes, 180 degrees out of phase with each other. Their outputs likewise will be out of phase. Interfering voltages reaching the input electrodes will also vary in phase and cancel each other leaving the desired signal from the nerve or muscle. This method of differentiating between the undesired in-phase and the desired out-of-phase signals has led to the designation of these amplifiers as "differential amplifiers." Matthews' design is reasonably inexpensive to build since single-ended stages may be used as second and third stages. Schmitt[7] built another simple differential amplifier requiring only two tubes, two rheostats, and a resistor, which also gave satisfactory results.

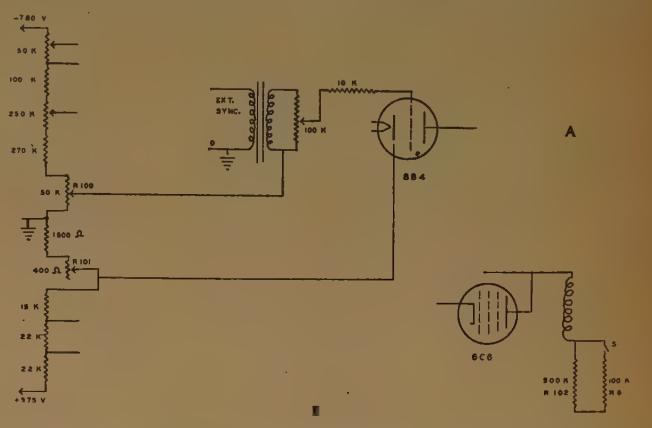


Fig. 2

A—Bleeder for power supply of cathode-ray oscilloscope showing trip-sweep adjustment. For original circuit see RCA No. 155 instruction bulletin (No. I.B.-26417, p. 12).
B—Modified plate circuit of horizontal amplifier.

More recently Toennies[5] has published data on a differential amplifier. In-phase cancellation is accomplished by employing a high-value cathode resistor which is common to both input tubes (*R*6 in Fig. 3). The high negative grid voltage resulting from this arrangement is compensated for by an opposition voltage or by returning the grids to ground through a positive potential. This input circuit differentiates with marked accuracy a modulation between two ungrounded points against the common modulation of these points. This amplifier may also be followed by single-ended stages. Recently, Traugott[4] in discussing an electroencephalograph design, objected to Toennies' circuit when low noise levels were necessary. Our experience confirms this objection. However, this amplifier does an excellent job of canceling in-phase signals.

## Interstage Coupling in Push-Pull Amplifiers

Offner[6] has reviewed several coupling methods for amplifiers when more than one push-pull stage is used.

[4] Paul Traugott, "Electroencephalograph design," *Electronics*, vol. 16, p. 132; August, 1943.
[5] J. F. Toennies, "Differential amplifier," *Rev. Sci. Instr.*, vol. 9, pp. 95–97; March, 1938.
[6] Franklin Offner, "Push-pull resistance coupled amplifiers," *Rev. Sci. Instr.*, vol. 8, pp. 20–21; January, 1937.
[7] Otto H. Schmitt, "A simple differential amplifier," *Rev. Sci. Instr.*, vol. 8, pp. 126–127; April, 1937.
[8] Brian H. C. Matthews, "A special purpose amplifier," *Jour. Physiol.*, vol. 8, pp. 28–29; 1934.

If a dual center tapped push-pull transformer is used to couple the first and second stages, no in-phase signal will result while the out-of-phase signals will be transmitted to the grids of the second stage. However, there are many practical objections to transformer coupling, one of which is the difficulty of obtaining adequate electromagnetic shielding. As a result, a resistance-capacitance coupling is used in most amplifiers for biological research.

One source of internal noise is the vibration of carbon particles when carbon resistors are used for coupling between low-level stages.[9] Wire-wound precision resistors are preferable for this purpose.

The amplifier that we are using consists of two push-pull stages with resistance-capacitance coupling, followed by three single-ended stages, each with an output jack which may be connected to the vertical plates of the cathode-ray oscilloscope (Fig. 3). The input stage uses tubes having a low noise factor (type 1603 RCA). The second push-pull stage is the differential stage, a slight modification of the Toennies design. An input jack to the grids of the second stage permits its use as the input stage when less amplification is needed. Input grid leaks are unnecessary since each grid electrode is in contact with two different points on the same nerve, whose resistance is between 1000 and 20,000 ohms. Thus, the nerve itself acts as a grid leak. When low-level signals are to be amplified, the first input stage is used as a differential preamplifier. By feeding a higher-level signal into the Toennies stage, we avoid much of the heater cathode disturbance objected to by Traugott.[4] We have also used successfully a three-stage push-pull amplifier with a volume control between the first and second stages. In studying spontaneous, rhythmic outbursts of action potentials, a loudspeaker is a distinct advantage. Records of electromyocardiograms demonstrated over a portable public address system,[10] illustrate this point.

The above-described apparatus has been put to use in our laboratory for the study of

1. Normal nerve-muscle physiology.
2. Fatigue.
3. Degeneration following nerve injury.[11]
4. Influence of vitamin E deficiency on neuromuscular function.
5. Action of drugs on peripheral nervous system and on muscles.

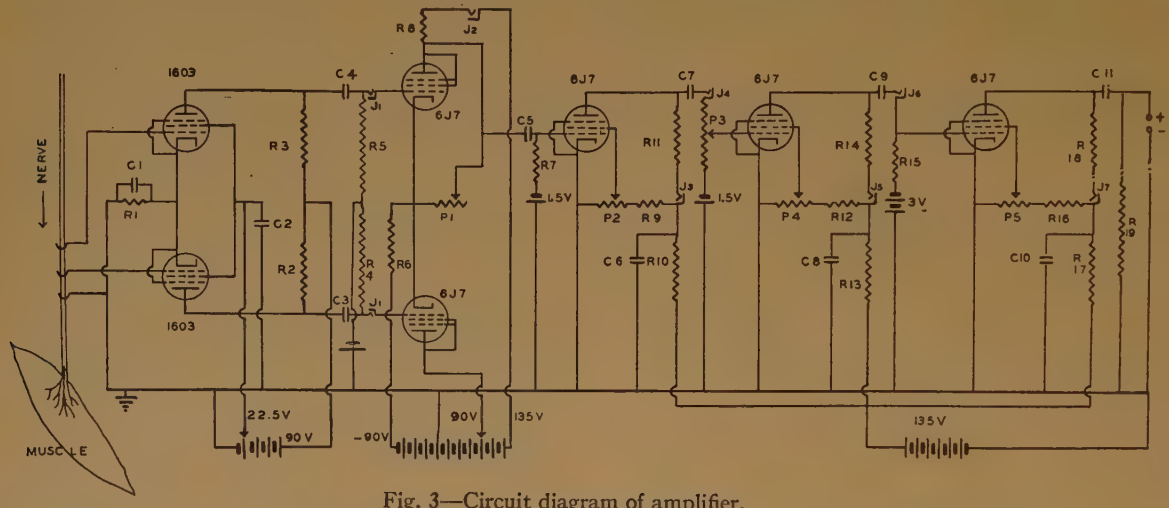


Fig. 3—Circuit diagram of amplifier.

$J_1$, $J_1$ are input jacks used when moderately high-level signals are being observed.
$J_4$ and $J_6$ are output jacks.
$J_2$, $J_3$, $J_5$, and $J_7$ are plate-current jacks into which a microammeter may be plugged when adjustments are to be made.
$P_1$, $P_2$ and $P_4$ are 0.5-megohm carbon potentiometers for regulating the screen voltage. A screw adjustment is on the front panel.
$P_3$ is a 0.5-megohm wire-wound potentiometer controlling the amplification of the last two stages.
$R_1$ is a 2500-ohm resistor
$R_2$, $R_3$, $R_4$, $R_5$, $R_7$, $R_{11}$, $R_{14}$, $R_{15}$, and $R_{18}$ are 0.5 megohm.
$R_9$, $R_{12}$, $R_{16}$, and $R_6$ are 0.1-megohm resistors.
$R_{19}$ is 1.0 megohm.
$R_8$ is 0.25 megohm.
$R_{10}$, $R_{13}$, and $R_{17}$ are 10,000-ohm resistors.
$C_1$ is a 50-microfarad condenser.
$C_2$ is 8 microfarads.
$C_3$ and $C_4$ are 0.1 microfarad.
$C_5$, $C_7$, $C_9$, and $C_{11}$ are 1.0 microfarad.
$C_6$, $C_8$, and $C_{10}$ are 12 microfarads electrolytic.
The heaters of all tubes are operated on 6-volt storage battery not shown in diagram.

Before discussing these uses it is desirable to make a few general statements regarding the nature of the nerve impulse. Although there are different schools of thought on this subject, the most widely accepted view is the Membrane or the Local Circuit Theory. According to this view, a resting nerve is enclosed in a semipermeable polarized membrane. When excited, the local area around the stimulating electrodes is depolarized. Stimulation apparently renders the surface temporarily permeable to the ions on each side of it, thus permitting them to pass through the membrane and neutralize each other. This depolarized area (labeled 0) is negative with

[9] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York, N. Y., 1943, p. 477.

[10] Made available through the courtesy of Arthur Washell.

[11] W. M. Rogers and H. O. Parrack, "Anatomico-physiological studies on degenerating peripheral nerves," *Anat. Rec.*, vol. 73, sup. 2, p. 44; April, 1939.

respect to the inactive remainder of the nerve. Thus, a difference in potential exists between the active and resting regions. The depolarized area is rapidly rebuilt by local currents from the inactive area. The region adjacent to the active area becomes depolarized, resulting in a wave of depolarization at approximately zero potential propagated along the nerve fiber (Fig. 4). This self-propagating surface breakdown accompanies the nerve impulse. For a brief time (0.4 to 2 milliseconds) after the passage of the impulse, the repaired area is refractory (Fig. 4). Stimuli falling within this refractory period are ineffective.

Strong support for the "membrane theory" was given by Lillie's[12] experiments. He prepared an iron-wire model which behaved like a nerve. The iron wire when treated with strong nitric acid becomes coated with an oxide film. When this coated wire was placed in a weak acid solution which would cause a gradual disintegration of an untreated wire, no chemical action resulted. The coated wire was said to be in a passive state, comparable to a resting nerve. The coated wire could be "stimulated" to activity by scratching the surface film or by applying an electric current. This initiates an electrochemical reduction which sweeps down the wire. It is

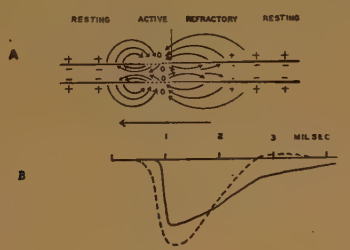


Fig. 4

A—Schematic representation of the membrane or local circuit theory. B—Impedance changes, solid line—action potential, dotted line.

accompanied by an effervescence and the production of a dark-colored lower oxide. By connecting two points along the iron-wire model with a galvanometer the passage of an electric current can be demonstrated. If the acid in which the model is immersed is of the proper concentration a new oxide film reforms in the wake of the reaction. A second stimulation will then cause a repetition of the same phenomenon. The resemblance of the reactions in the iron-wire model to those in a living nerve is very striking. Both are surface phenomena. Recent work of Cole and Curtis[13] also supports the membrane theory. They measured the impedance changes during activity in the giant nerve fibers of the squid. A definite decrease of impedance occurs when the nerve impulse passes any given point. This impedance change occurs suddenly at the moment when the action potential reaches its maximum (Fig. 4B). They consider that the breakdown consists in the sudden and simultaneous change of the membrane electromotive force and conductance which are closely associated properties of a nerve. The current which flows through the membrane reverses in direction at the same time that conductance increases.[14] Impedence changes and potential differences should both be regarded as electrical signs of nerve function.

When alternating-current differences in potential are recorded on a cathode-ray oscilloscope they cause a deflection for each of a pair of grid electrodes in push-pull arrangement. These two deflections are spoken of in electrophysiology as a diphasic action potential which is bidirectional and whose alternate phases cross the zero line (Figs. 5A and 6). A steady current called the current

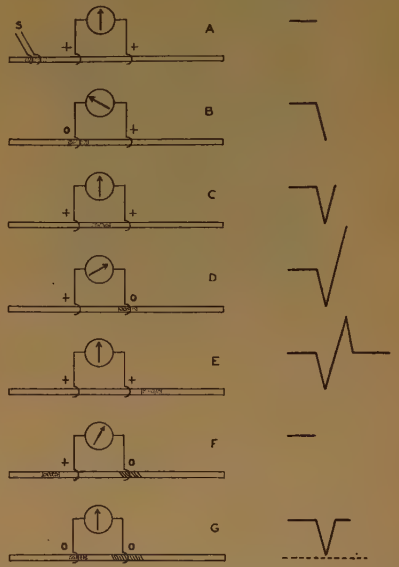


Fig. 5—Simplified diagram of current (left side) and potential (right) changes as recorded on a galvanometer and on a cathode-ray oscilloscope (right) during passage of a nerve impulse. *S* indicates the stimulating electrodes.

of injury may be obtained by crushing the area in contact with the second grid electrode (crosshatched). This may be recorded on the galvonometer but not on the cathode-ray oscilloscope (Fig. 5F). If this preparation is stimulated only one deflection will be recorded on the cathode-ray oscilloscope. This deflection, called a monophasic action potential is unidirectional (does not cross the zero line) and will occur when the impulse (stippled area) reaches the first electrode (Figs. 5G and 7). The maximum deflection approaches the level of zero difference of potential (broken line). Due to crushing of the nerve the impulse never reaches the second electrode.

## Conduction Rate

In addition to measuring the amplitude and analyzing the wave form we can study the conduction rate of the nerve impulse. This may be done in several ways, one of which is described below. The first of two pairs of recording electrodes $L_1$ is in contact with the nerve

[12] R. S. Lillie, "Transmission of physiological influences in protoplasmic systems, especially nerves," *Physiol. Rev.*, vol. 2, pp. 1–33; January, 1922.

[13] K. S. Cole and H. J. Curtis, "Electrical impedance of nerve during activity," *Nature*, vol. 142, pp. 209–210; July, 1938.

[14] H. J. Curtis, "Macleod's Physiology in Modern Medicine," ninth edition, C. V. Mosby Company, St. Louis, Missouri, chapter 7, "The Nerve Impulse."

distal to the stimulating electrodes. At some point distal to the first pair of recording electrodes is a second pair of recording electrodes $L_2$. The diphasic wave recorded by $L_1$ is nearer the shock effect than is the wave recorded by $L_2$ (Fig. 6). A time recording superimposed on the same figure permits us to compute the conduction rate when the distances between $S$, $L_1$, and $L_2$ are known. It has been shown by Erlanger and Gasser[1] that the conduction rate varies with the fiber size (Fig. 7B)[15] and

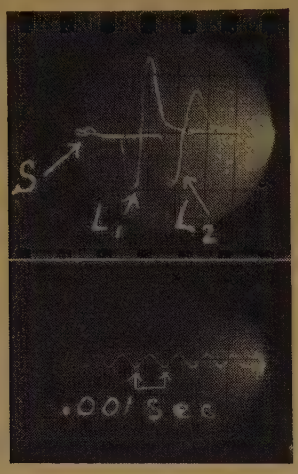


Fig. 6—Diphasic-action potential records.

with the temperature. The conduction rate of the largest fibers (18$\mu$) in the nerves of bullfrogs and other cold-blooded animals is 40 to 42 meters per second (Fig. 6). In mammals and other warm-blooded forms, fibers of the same size have a more rapid rate of conduction (90 to 100 meters per second). Most nerves contain fibers of several diameters, each having a different conduction rate (Fig. 7). The smaller the fiber, the slower its rate.

The threshold necessary to excite the large fibers is less than that required for smaller ones. Fig. 7A is an action-potential record of the largest fibers, designated as $\alpha$ in the sciatic nerve of a bullfrog. The stimulating pulse of 3 volts was sufficient to excite every large fiber. By increasing the voltage (4 to 6 volts) the group of slightly smaller (14$\mu$) fibers were activated. The potential from this group, designated as $\beta$, appears as a second, smaller elevation which follows the $\alpha$ spike along the time axis since the smaller fibers have a slower conduction rate (25 meters per second).

One can observe that the amplification is the same for the two records by comparing the alpha spikes. In Fig. 7A the voltage pulse, which reaches both grid leads at

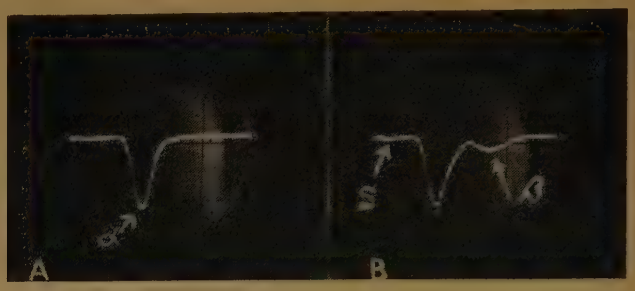


Fig. 7—Monophasic-action potential records.

practically the same time, is entirely canceled. In 7B the increased pulse ($S$) is barely discernible.

## Transmission of Impulse from Nerve to Muscle

Where a motor-nerve fiber terminates on a skeletal muscle fiber, it does so through a specialized ending, called a motor end-plate. Around the nerve terminals is a special substance which transmits the impulse across the nerve-muscle junction and initiates changes in the muscle fiber. When the nerve is stimulated in a normal nerve-muscle preparation, action potentials may be picked up from the nerve by a first set of recording electrodes while the potentials from the muscle may be recorded by a second set. Following prolonged rapid stimulation, the muscle finally fails to contract when the nerve is stimulated, but contracts when the muscle is stimulated directly. Records taken from such a fatigued nerve-muscle preparation show action potentials in the nerve but not in the muscle, indicating that the motor end-plate is the site of fatigue. The same principle has been used in studying the cause of failure in degenerating nerve[16] and in various drug experiments.

[15] All photographic records used were made with a Leica 35-millimeter camera using an $f/2$ lens and either super XX or ultra-speed film.

[16] W. M. Rogers and H. O. Parrack, "Influence of age on functional survival of severed mammalian nerves," *Proc. Amer. Physiol. Soc.*, p. 611P, listed in *Amer. Jour. Physiol.*, vol. 126, no. 3, July, 1939.

# Electrical Glass*

EDWIN M. GUYER†, ASSOCIATE, I.R.E.

*Summary*—**Electrical glass offers the electronics engineer a versatile working medium with useful applications in many types of circuit elements, a dielectric with properties suitable for solving some of his most perplexing problems in electrical insulation.**

**The behavior of electrical glass in direct-current and in alternating-current fields is discussed in terms of dielectric properties, considered as functions of field parameters and variables of ambient condition.**

**Representative values are given in the form of curves which illustrate the wide range of glass properties available for radio engineering service.**

## Introduction

FROM a practical engineering viewpoint, glass is silica which has been rendered thermoplastic at a convenient working temperature by admixture of borate and alkaline oxide fluxes in combinations and amounts carefully formulated to enhance certain specific properties. The variety of shaping and forming operations thus made possible is unique among modern manufacturing methods.

Electrical glass is glass formulated to meet the special requirements for optimum performance in a wide variety of electrical applications. It serves the radio engineer in four distinctly different ways:

(1) As an insulator to confine the flow of electric current in suitably restricted channels.
(2) As a conductor of electrical energy in the form of alternating potential waves.
(3) As a storage medium for electric energy.
(4) As a vacuum or gastight envelope for numerous electronic devices ranging from miniature radio tubes to giant rectifier bulbs and including sealed housings for such circuit elements as condensers, resistors, and inductors.

But the glass characteristics necessary for successful operation are not limited to electrical properties alone. Thermal, mechanical, and even chemical properties must not be neglected in the business of accurately fitting electrical glass to the service which it is expected to perform.

## Thermal Strength

Since the insulation on high-powered, high-voltage systems is sometimes exposed to thermal shock from superficial electrical discharges or flashovers, good arc resistance is an important criterion in the selection of a serviceable material. The remarkably low coefficients of thermal expansion of borosilicate glasses render them highly commendable for this type of service.

## Mechanical Strength

In compression, glass is very strong, resisting with impunity crushing forces which would make metals and other structural materials crumble or flow like wax. Since glass is a very hard material, it breaks in tension at lower stresses than it can safely withstand in compression. Thus it is often possible, where great mechanical strength is an important design consideration in an electrical-insulation problem, to process the glass by suitable heat treatment in such a manner that the outside exposed surface is under compression. When this is done properly, the strength may be increased by a factor of three or more.

It is the purpose of this discussion to analyze in terms of characteristic properties those factors which determine the electrical behavior of glass in the difficult insulation problems with which the radio engineer is frequently confronted. In Part I the behavior of glass will be considered in direct-current electrical fields. Part II will deal with glass behavior in alternating-current fields, and in Part III certain special forms of electrical glass will be described. From the wide range of glass properties available, representative values will be given to help in the selection of proper glasses for optimum performance under various conditions of service.

## PART I

### Behavior of Glass in Direct-Current Electric Fields

In a unidirectional electrical field of constant intensity the behavior of glass as an electrical insulator is determined and controlled by four fundamental electrical properties:

1. Surface electrical resistivity
2. Volume electrical resistivity
3. Specific inductive capacitance or dielectric constant
4. Dielectric strength

Although these properties are to be considered as characteristic of the material, they are definitely modified by ambient conditions. Thus the satisfactory solution of an electrical-insulation problem involving glass, or any other dielectric, requires knowledge of the basic properties considered, not as single valued constants, but as dependent variables in functional relationship with one or more of four independent variables of ambient condition: (1) time, (2) temperature, (3) relative humidity, and (4) atmospheric pressure.

### Surface Electrical Resistivity

Surface electrical resistivity is of primary importance in all electrical insulation problems since it affects directly actual performance in service. Due to the adsorption of a moisture film, the surface electrical resistivity of glass, while high in comparison with that of

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† Corning Glass Works, Corning, New York.

many other materials, is markedly lower than volume resistivity. Thus chemical durability is an essential requirement in good electrical glass since moisture-film thickness and conductivity both are increased by soluble products of unstable compositions.

Fig. 1 is a plot of representative values showing surface resistivity as a function of relative humidity at 20 degrees centigrade for fused quartz, an ordinary lime glass, and a high-quality borosilicate electrical glass.

The dotted line at the top indicates the order of additional insulation (with respect to surface resistivity)

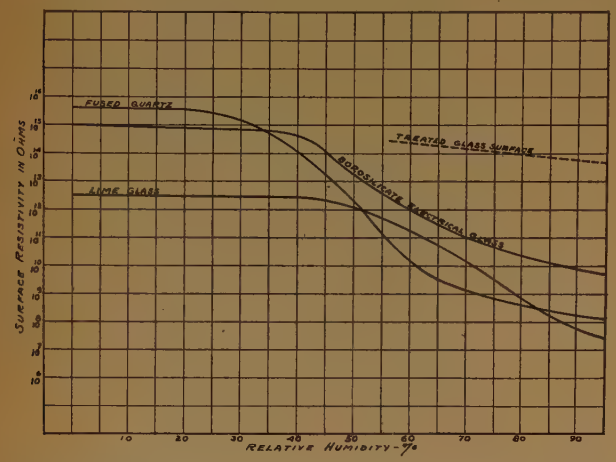


Fig. 1—Surface resistivity as a function of relative humidity for fused quartz, borosilicate electrical glass (Corning no. 774), and lime glass (Corning no. 008).

which can be achieved by means of special surface treatments.

## Volume Electrical Resistivity

Volume resistivity when measured in terms of current flowing through unit path per unit of applied voltage, in accordance with Ohm's law for metallic conductors, is markedly affected in glass and other dielectrics by several factors which must be specified to obtain valid results. The current flowing at any instant after application of the voltage is determined not only by the instantaneous voltage and temperature which prevail at the moment of measurement but is a function also of the time which has elapsed since the initial application of voltage, the previous electrical and thermal history of the sample under test,[1] the composition of the glass, and, in some instances, the composition of the electrodes used to contact the glass.[2] This functional relationship between current strength and elapsed time of flow, called dielectric absorption, has been known to students of dielectrics beginning with Benjamin Franklin and studied since that time by an imposing list of famous scientists.[3,4]

[1] E. M. Guyer, "Electrical behavior of glass at room temperature," *Jour. Amer. Ceram. Soc.*, vol. 16, pp. 607–618; December, 1933.
[2] H. R. Kiehl, "Electrical conductivity of glass," *Physics*, vol. 5, pp. 363–369; December, 1934.
[3] John Hopkinson, "Original Papers," vol. 2, Scientific, Cambridge University Press, London, England, 1901, pp. 1–153.
[4] J. B. Whitehead, "Lectures on Dielectric Theory and Insulation," McGraw-Hill Book Company, New York, N. Y., 1927, chapter 2, pp. 18 et. seq.

Dielectric absorption appears as a superposed transient current many times greater in magnitude than the final true electric conduction current by which it is ultimately succeeded. In Fig. 2, a typical charge-and-discharge curve for a lead borosilicate glass plate provided on opposite faces with metal electrodes illustrates several important facts with regard to dielectric absorption in electrical insulation.

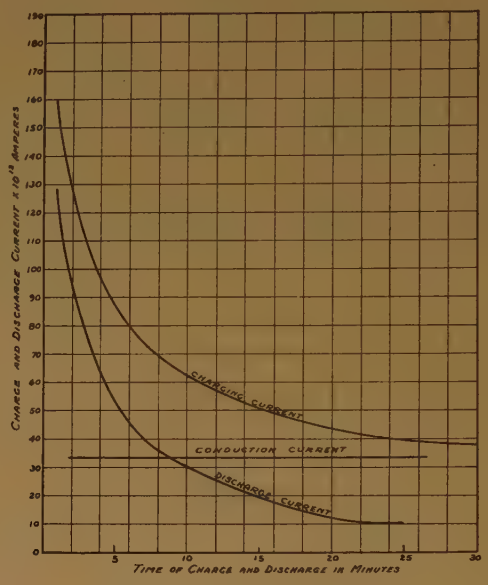
CHARGE AND DISCHARGE CURRENT X 10^13 AMPERES
CHARGING CURRENT
CONDUCTION CURRENT
DISCHARGE CURRENT
TIME OF CHARGE AND DISCHARGE IN MINUTES

Fig. 2—Charge and discharge curves for a lead borosilicate glass (Corning no. 772).

It will be observed that while a current of $160\times10^{-13}$ ampere flowed through the glass at room temperature (20 degrees centigrade) one minute after application of voltage, the current has dropped to $41.5\times10^{-13}$ ampere after twenty-five minutes of applied voltage. This decrease is current continues for hours depending upon glass composition and temperature, the disappearance of the anomalous current taking place faster at higher temperatures.

From this observation two things are clear. The conventional arbitrary adoption of one minute of elapsed time after the initial application of voltage is unsatisfactory as a standard procedure for glass-resistivity measurements. On the other hand, continued observations until the apparent change in resistivity has decreased to the limits of accuracy of measurement is impracticable where more than a very few samples are to be measured. Fortunately there is a relatively simple solution to this problem since in good electrical glasses the dielectric absorption is reversible. Thus by plotting two curves, one showing the charging current for an interval of time which should be increased (within limits) the greater the desired precision, and the other the discharge current, after voltage removal for a similar interval, it will be found that subtraction of ordinates of the discharge curve from corresponding ordinates of the charge curve will yield values which approximate the true conductivity. This procedure is illustrated in Fig. 2.

Volume resistivity of glass at ordinary room temperatures varies widely with composition from glasses as low as $10^8$ ohm centimeters in resistivity to glasses as high as $10^{19}$ ohm centimeters. The resistivity of a given composition at a fixed temperature may vary by a factor of 3 depending upon the degree of annealing or strain which the glass has received, strained glass having lower resistance than properly annealed glass.

At temperatures well above room temperature, anomalous absorption currents become insignificant in relatively short intervals of time so that these effects are

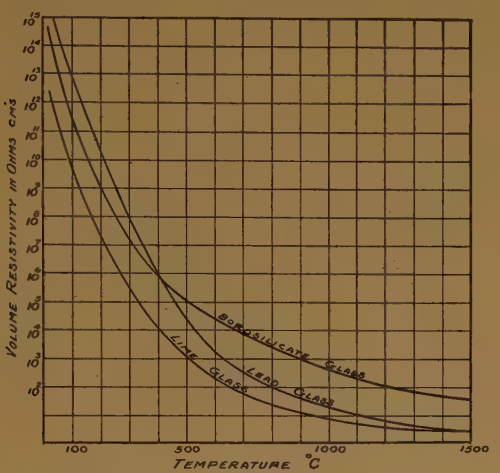


Fig. 3—Volume resistivity as a function of temperature for borosilicate glass (Corning no. 774), lead glass (Corning no. 001), and lime glass (Corning no. 008).

no longer troublesome in volume-resistivity measurements. However, considerable time must be allowed, even at elevated temperatures, for the glass to stabilize, that is, attain a final constant value at the temperature in question.[5]

Fig. 3 illustrates the variation in volume resistivity of three representative types of glass: a lime glass, a lead glass, and a borosilicate electrical glass, over the wide temperature range from ordinary ambient temperatures of 20 to 1500 degrees centigrade. The superiority of the high lead and borosilicate electrical glasses over lime glass is evident.

## Specific Inductive Capacitance or Dielectric Constant

Dielectric constant, defined as the ratio of the capacity of a given electrode configuration including a specific dielectric to the capacitance of this same electrode system in vacuum (without the dielectric), varies with glass composition from a little less than 4 to values of 16 and over.

In direct-current fields at ordinary room temperatures dielectric absorption affects dielectric constant measurements giving values which vary with the time of applied potential or charging time. Curie and Compan[6] observed increases in dielectric constant of 43 per cent from 7.89 to 11.25 for potash-lime glass for variations in time of charge from 0.05 second to 10 seconds. At very low temperatures (−75 degrees centigrade) dielectric constant has been found to be independent of time of charge. At ordinary room temperatures and above, dielectric constant increases markedly with temperature at rates which vary with glass composition, being least in high silica and borosilicate electrical glasses and greater in lime glasses containing substantial amounts of alkali.

In addition to the obvious effect of high-dielectric-constant glasses on the capacitance of the circuit elements into which they enter, it is to be noted that their high-dielectric strengths may be of even greater significance in energy-storage systems. Since the energy which can be stored in a condenser varies as the first power of the dielectric constant and the second power of the voltage, a glass with twice the dielectric strength is as effective as one with four times the dielectric constant.

## Dielectric Strength

While the surface and volume resistivities together with the dielectric constant each affect the behavior of glass in direct-current fields of arbitrary intensity, the important matter of how great the voltage can safely be allowed to grow without danger of breakdown is determined by the fourth property, the dielectric strength. Of all four properties, dielectric strength is the most difficult of measurement and the least certain of interpretation. A good deal has been written in the literature on the physical mechanisms responsible for the complex behavior but much remains to be established before there can be satisfactory agreement between the different theories so far advanced. Meanwhile, the engineer must content himself with testing dielectrics for electrical breakdown under circumstances as nearly identical with actual service conditions as possible, proceeding cautiously when definite departures from these test conditions are unavoidable.

The voltage gradient, across the dielectric, at which electrical failure takes place varies with (1) the characteristics of the ambient testing medium, (2) the nature and manner of application of the impressed electric field, and (3) the composition, form, and condition of the glass sample under test.

Failure to specify the variables controlling each of these separate factors accounts for the difficulty in correlating much of the recorded data on dieletric strength.

Although a detailed analysis is beyond the scope of this discussion, an excellent critical examination of this complex problem has been given by Littleton and Morey[7] from which certain observations are here summarized to help in the proper selection and treatment of glass dielectrics for high-voltage service.

Because the dielectric strength of glass is much

[5] J. T. Littleton and W. L. Wetmore, "The electrical conductivity of glass in the annealing zone as a function of time and temperature," *Jour. Amer. Ceram. Soc.*, vol. 19, pp. 243–245; September, 1936.

[6] Curie and Compan, *Comptes Rendus*, vol. 134, p. 1295; 1902.

[7] J. T. Littleton and G. W. Morey, "The Electrical Properties of Glass," John Wiley and Sons, Inc., New York, N. Y., 1933, chapter V, "Dielectric Strength."

greater than most other substances including the air and conventional insulating liquids such as oil, used for convenience to avoid surface flashover, the results obtained in such tests are characteristic of the weaker medium in which the glass is tested rather than the glass itself.

What is actually measured is not so much dielectric strength as corona resistance or the ability to withstand bombardment with the ions from the localized discharges occurring in the weaker gaseous or liquid medium. Different glasses and even nonvitreous products with widely different dielectric strengths will thus appear to have the same breakdown voltage, namely, that of the oil in which they are tested, and in different oils, will show as many different apparent dielectric strengths.

The only remedy seems to be the application of special techniques of measurement which avoid the localized discharges at points of nonuniform electrical stress concentration in the medium about the test electrodes.

In considering briefly the effect of composition, form, and condition of the glass on dielectric strength, it should be noted that it was not until procedures were developed which eliminated edge effect that results were available which were sufficiently consistent to separate the controlling factors.

Glass temperature determines not only the magnitude of the breakdown voltage but also the type of dielectric failure. At low temperatures and with thin sections, glass fails by purely disruptive breakdown, resulting directly from electrical overstress of the dielectric without evidence of internal heating.

At higher temperatures the breakdown is largely of the thermal type. Dielectric heating becomes cumulative as losses raise the temperature which, in turn, increases the dielectric loss. The upper curve of Fig. 4 shows the variation of the dielectric strength of lime glass with temperature in the thermal breakdown region. Moon and Norcross[8] working with samples of 200 micron thickness found the following relative values of breakdown voltage in the disruptive region and thermal breakdown region at 300 degrees centigrade for the four types of glass illustrated.

TABLE I

| Kind of Glass | Disruptive kilovolts per centimeter | Thermal kilovolts per centimeter |
|---|---|---|
| Fused-quartz glass | 5000 | 560 |
| Borosilicate glass | 4800 | 200 |
| Lead glass | 3100 | 102 |
| Lime glass | 4500 | 32 |

As expected, glass compositions which show highest electrical resistivity at elevated temperatures have, in general, highest dielectric strength for thermal breakdown at the elevated temperatures. This does not imply correlation, however, between dielectric strength and electrical resistivity at low temperatures.

[8] P. H. Moon and A. S. Norcross, "Three regions of dielectric breakdown," *Elec. Eng.*, vol. 49, p. 762; April, 1930.

Disruptive breakdown voltage increases directly with thickness. Thermal breakdown gradient, on the contrary decreases for thicker sections due largely to cumulative overheating. This will be discussed further in considering glass behavior in high-frequency fields.

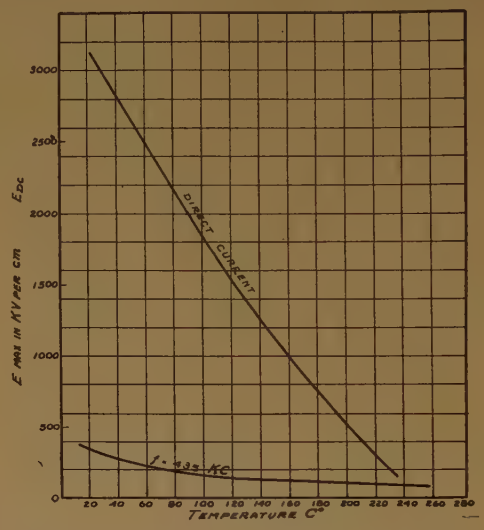


Fig. 4—Breakdown voltage as a function of temperature for direct current and for 435-kilocycle alternating current.

## PART II

### Behavior of Glass in Periodic Electric Fields

The behavior of glass (and all other dielectrics) in fields which vary periodically in intensity and direction is dominated by the phenomena of dielectric loss. Anomalous absorption currents are predominant over conduction currents since the time of current flow between reversals of the field is, in practice, much shorter than the time duration of the transient absorption currents. Dielectric absorption, plus conduction, transforms electrical energy into heat since both represent components of current flow in phase with the alternating electric field, in contrast to the 90-degree phase relation between the current and voltage vectors of a hypothetical wattless condenser. Inasmuch as all properties, electrical, mechanical, and chemical, vary with temperature, it is obvious that the primary factor which determines the rate of heat generation in the cyclically polarized dielectric will control the consequent variations in all of these properties. In operation at low voltages and power levels, low-loss insulation is desirable to improve circuit performance. At high voltages and power levels, dielectric losses must be minimized not only to improve circuit performance but also to avoid destruction of the insulation itself by cumulative heating. Thus it is of primary concern in the selection of high-frequency insulation to know how much of the field energy will be wasted in heating up the dielectric and how this will affect the life and performance of the insulated system.

### Dielectric Loss

Energy expended by the field in heating up the insulation is represented vectorially by the dielectric

power factor or loss angle which is the complement of the phase angle between the impressed sinusoidal voltage and resultant dielectric current. More specifically it can be represented by the loss factor which is the product of the tangent of the loss angle and the dielectric constant.[9]

Power loss in watts per unit volume of dielectric, per cycle, per unit potential gradient, may be expressed conveniently in terms of a numerical unit constant, and the loss factor $LF$. Thus since the power loss varies directly with frequency of the applied voltage and the square of the potential gradient, power loss in watts per

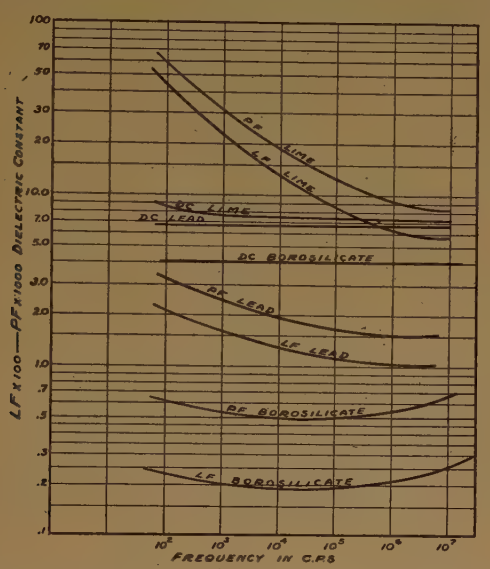


Fig. 5—Variation of power factor ($PF$), loss factor ($LF$), and dielectric constant ($DC$) with frequency for borosilicate glass (Corning no. 707), lead glass (Corning no. 001), and lime glass (Corning no. 008).

unit volume may be calculated at any specified frequency and voltage by the equation:

$$P/V = 0.555LF \cdot f \cdot E_g^2 \qquad (1)$$

where $f$ is frequency in megacycles, $E_g$ is potential gradient in kilovolts per centimeter, and $LF$ is the product of the dielectric constant (ratio without dimensions) and tangent of the loss angle.

Fig. 5 shows the variation of the loss factor with frequency over the wide range from 60 cycles to 10 megacycles per second, for three representative glasses, a high-quality borosilicate and a lead glass suitable for radio service, and, for purposes of comparison, an ordinary lime glass. The marked superiority of the radio glasses is evident.

While in all cases the loss factor is relatively much higher at the lower frequencies, the need for the higher-quality glasses is nevertheless more urgent at the high-frequency end of the spectrum since it is the actual loss in watts per unit volume of dielectric which determines radio field performance. An equally important consideration is the variation of the loss factor with temperature since dielectric heating increases dielectric losses cumulatively. Fig. 6 (right) shows the variation with temperature of loss factor, for a high silica and a low alkali borosilicate electrical glass in comparison with fused quartz.

While in most high-frequency insulation problems the loss factor is the most important consideration, there are some electrical-glass applications, such as capacitor design, where knowledge of the behavior of each component, the dielectric constant, and the power factor considered separately, is of interest.

## Power Factor

Power factor varies with glass composition, the frequency of the applied field, and the temperature of the glass. Fig. 5 shows this variation of power factor with frequency for a low-loss borosilicate glass, a lead glass, and for an ordinary soda-lime glass. Fig. 6 (left) shows the behavior of the power factor with respect to temperature.

Expanded plots for both dielectric constant and power factor for several representative glasses measured in

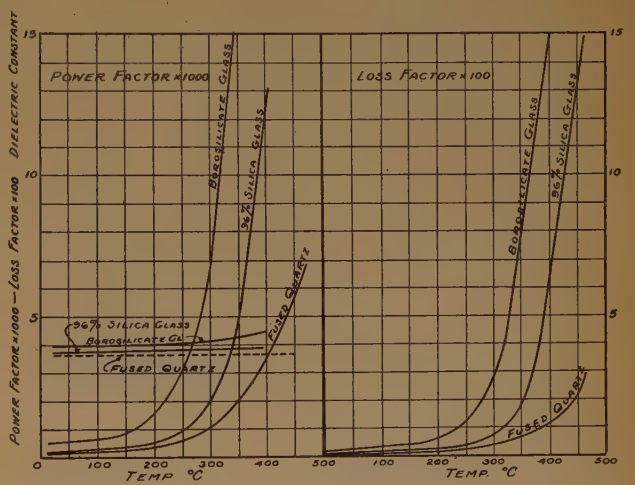


Fig. 6—Power factor and loss factor as functions of temperature for fused quartz, borosilicate glass (Corning no. 707), and 96 per cent silica glass (Corning no. 790).

round-robin tests in several different laboratories, over a wide range of frequencies will be found in a paper by Richards.[10]

## Dielectric Constant in Alternating-Current Fields

The dielectric constant of most glasses decreases as the frequency of the applied field increases, the variation being large for high-loss glasses and relatively much less for low-loss electrical glass. Rising temperature increases dielectric constant but the percentage increase is less at high frequencies than at low.

This behavior is illustrated in Figs. 5 and 6.

## Surface and Volume Resistivity

Surface and volume resistivity are of considerably less importance in alternating-current fields than in direct-current fields because of the relatively much

[9] E. T. Hoch, "Power losses in insulating materials," *Bell Sys. Tech. Jour.*, vol. 1, pp. 110–117; November, 1922.

[10] P. A. Richards, "Report on round-robin tests of power factor and dielectric constant for glass," *Amer. Soc. Test. Materials Proceedings*, 44th Annual Meeting, vol. 41, pp. 1183–1197; June, 1941.

greater magnitudes of the dielectric-displacement currents in comparison with the conduction currents. Unless ambient temperature and humidity are very high, only a small part of the total dielectric loss in high-frequency fields can be accounted for by electrical conductivity.

Yager and Morgan[11] have shown the part played by surface and volume conductivity in determining glass behavior in high frequency fields.

The family of curves in Fig. 7 (from their paper) shows the variation in surface conductivity of a borosilicate electrical glass with relative humidity at different frequencies and temperatures. Surface conductivity is seen to increase with frequency and to a greater extent at higher humidities than at lower. While surface conductivity increases with ambient temperature this

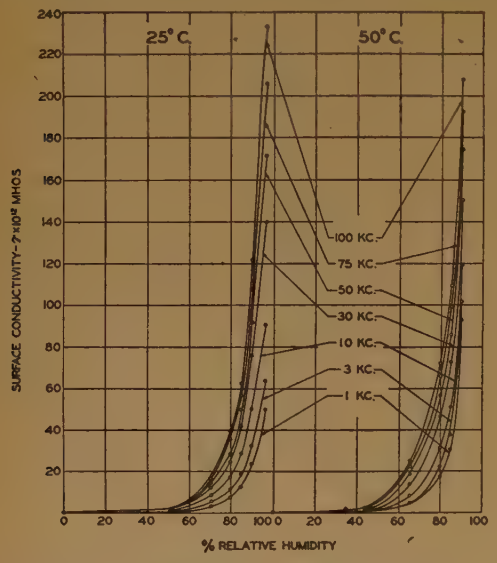


Fig. 7—Surface conductivity as a function of relative humidity at different frequencies.

factor of increase is relatively small in comparison with the changes due to variations in either the frequency or the relative humidity.

### Dielectric Strength in Alternating-Current Fields

At low temperatures and frequencies, under conditions such that edge effect is properly eliminated and breakdown is disruptive in character, most investigators have found no difference in the dielectric strength of glass whether determined by impulse test, in direct-current fields, or in alternating-current fields, provided peak voltage is used as the basis of comparison. Because of the phenomena of dielectric loss, however, it is apparent that thermal breakdown will play an increasingly important role in glass behavior in alternating-current fields and that this fact will become more pronounced at the higher frequencies. Thus dielectric failure in practice is largely determined by the thermal parameters of the glass system and ambient medium in addition to the electrical characteristics of the glass and the dielectric loss factor becomes an essential part of high-frequency dielectric strength.

This is illustrated in Fig. 4 where the breakdown voltage is seen to decrease at 20 degrees centigrade from over 3000 kilovolts per centimeter for direct current to less than 400 kilovolts per centimeter at 435 kilocycles.

The relatively much smaller difference between direct-current and high-frequency breakdown at higher glass temperatures is also apparent. Thus for the lime glass in question there is no difference between high and low frequency breakdown at temperatures above 240 degrees centigrade.

A comprehensive summary of alternating-current dielectric-strength data on glass collected from many different sources and presented in convenient graphical form will be found in a recent paper by Shand.[12]

## PART III

### Special Forms of Electrical Glass

Certain special forms of electrical glass which are rapidly finding useful applications in the electrical insulation field are the product of new processes involving radical departures from established methods of glass fabrication are (1) fiber glass electrical insulation, (2) multiform electrical glass, (3) VYCOR brand 96 per cent silica electrical glass, and (4) new combinations in glass-metal seals.

### Fiber-Glass Electrical Insulation

Fiber glass, as applied in electrical-insulation tapes, braided sleeving, electrical cloth, cordage, laminated products, and mica combinations, owes its success to the extraordinary tensile strength of fine glass fibers, their resistance to temperature, and their desirable electrical properties. Motors, generators, transformers, reactors, relays, meters, and all manner of electromagnetic equipment have profited by the reduction of winding space and higher safe operating temperatures which fiber-glass insulation provides. Even after treatment with suitable impregnating varnishes the marked superiority of these inorganic fibers is still dominant over comparable products similarly treated, as illustrated in Figs. 8 and 9.

### Multiform Electrical Glass

In the past the production of electrical glass parts by conventional glass making methods—blowing, pressing, and drawing—have had definite limitations. Shapes have had to be relatively simple and special design features such as holes, grooves, or threads have been major problems for the glassmaker. It has also been difficult with the conventional methods to hold close tolerances in the dimensions of glass parts. The results of these limitations in shape, design, and accuracy has

[11] W. A. Yager and S. O. Morgan, "Surface leakage of pyrex glass," *Jour. Phys. Chem.*, vol. 35, pp. 2026–2042; 1931.

[12] E. B. Shand, "The dielectric strength of glass—An engineering viewpoint," *Elec. Eng.*, vol. 60, pp. 41–91; March, 1941.

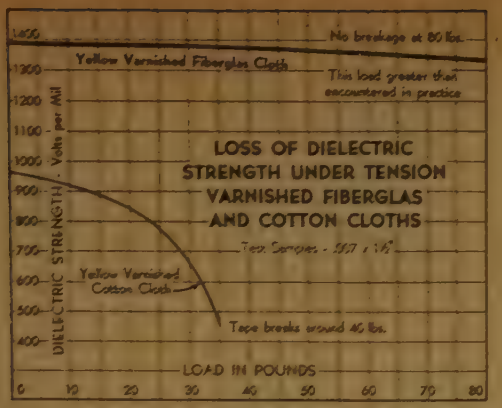
No breakage at 80 lbs.
Yellow Varnished Fiberglas Cloth
This load greater than encountered in practice
LOSS OF DIELECTRIC STRENGTH UNDER TENSION VARNISHED FIBERGLAS AND COTTON CLOTHS
DIELECTRIC STRENGTH - Volts per Mil
Yellow Varnished Cotton Cloth
Tape breaks around 45 lbs.
LOAD IN POUNDS

Fig. 8—Loss of dielectric strength under tension varnished fiberglas and cotton cloths.

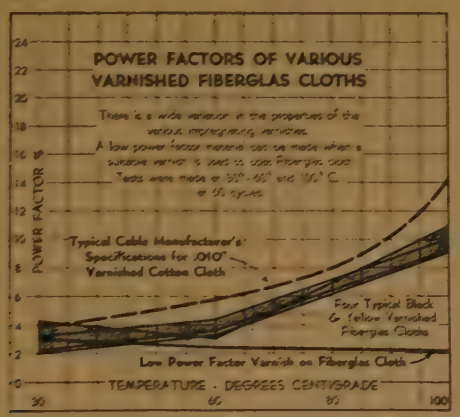
POWER FACTORS OF VARIOUS VARNISHED FIBERGLAS CLOTHS
POWER FACTOR
Typical Cable Manufacturer's Specifications for .010" Varnished Cotton Cloth
Four Typical Black & Yellow Varnished Fiberglas Cloths
Low Power Factor Varnish on Fiberglas Cloth
TEMPERATURE - DEGREES CENTIGRADE

Fig. 9—Power factors of various varnished fiberglas cloths.

been to preclude the use of glass in many applications where the qualities of the material have been suitable.

A wide range of new applications of electrical glass has been made available by the recent development at Corning of the Multiform process of glass making, in which successful production of intricate insulating parts of unusual shape and with close dimensional tolerances has been achieved. A number of glass compositions having widely different characteristics are available and have found applications in products ranging from small insulating beads, running several thousand to the pound to large insulators and bushings weighing 25 pounds or more.

General dimensional tolerances are: large or heavy pieces, intricate shapes, hollow cylindrical sections—$\pm 2.0$ per cent or 0.010 inch; flat plates, solid rods, disks, beads, bushings—$\pm 1.0$ per cent or 0.005 inch, excepting thickness which should be $\pm 4.0$ per cent or 0.01 inch. This glassware can be ground and polished to closer tolerances when necessary.

Properties of glasses made by the Multiform process are given in the following table in comparison with glass No. 774 made by conventional processes.

The range of practical design of glass parts for all manner of electrical-circuit elements from coil forms and capacitors to fittings and internal insulating structures for electronic tubes is enormously extended by the development of the Multiform process.

TABLE II

GLASSES MADE BY MULTIFORM PROCESSES COMPARED TO NO. 774 GLASS MADE BY CONVENTIONAL PROCESSES

| Process Glass No. | Unit | Multiform 790 | Multiform 7761 | Multiform 707 | Conventional 774 |
|---|---|---|---|---|---|
| Linear coefficient expansion (0–300 degrees centigrade) | per degrees centigrade $\times 10^{-7}$ | 7.5 | 33 | 32 | 33 |
| Maximum service temperature | degrees centigrade | 800 | 460 | 450 | 510 |
| Log R at 250 degrees centigrade | ohm centimeters | 9.8 | 12.0 | 11.2 | 8.1 |
| Log R at 350 degrees centigrade | ohm centimeters | 8.1 | 10.0 | 9.1 | 6.7 |
| Power factor at 1 megacycle 20 degrees centigrade | per cent | 0.10 to 0.18 | 0.11 | .08 | 0.42 |
| Dielectric constant at 20 degrees centigrade 1 megacycle | | 4.0 | 4.0 | 4.0 | 4.7 |

## VYCOR BRAND 96 PER CENT SILICA ELECTRICAL GLASS No. 790

This glass is approximately 96 per cent silica and compares favorably with fused quartz in thermal properties and performance. For operations at very high temperatures and insulating problems where high arc resistance is desirable, it is a marked advance over all other glasses with the exception of pure fused silica. Because of newly developed methods of manufacture, glass No. 790 can be fabricated and formed as an easily workable glass of relatively low melting point after which a special chemical process removes practically all constituents except silica. A high-temperature firing subsequently consolidates this porous shell into the finished ware. Its properties are compared with other materials as shown in Table III.

TABLE III

CHARACTERISTICS OF GLASS NO. 790 COMPARED TO OTHER MATERIALS

| Physical Property | 96 Per Cent Silica Glass No. 790 | Pyrex Brand Glass No. 774 | Fused Silica |
|---|---|---|---|
| Softening point, degrees centigrade | 1500 | 819 | *1667 |
| Annealing point, degrees centigrade | 910 | 553 | *1140 |
| Strain point, degrees centigrade | 820 | 510 | *1070 |
| Maximum operating temperature, degrees centigrade | 900 | 510 | 1000 |
| Linear coefficient expansion per degree centigrade (From 0 to 300 degrees centigrade) | $7.5 \times 10^{-7}$ | $33 \times 10^{-7}$ | $*5.5 \times 10^{-7}$ |
| Specific gravity | 2.18 | 2.23 | *2.20 |
| Index of refraction | 1.458 | 1.474 | *1.458 |

* General Electric Company.

## NEW COMBINATIONS IN GLASS-METAL SEALS

As the large family of present-day electronic tubes continues its rapid growth, both in number and variety, the problem of sealing electrically conducting vacuum-tight leads into the insulating glass envelopes of vacuum and low-pressure discharge devices confronts the tube engineer with ever greater frequency. Rising power levels demand larger conductors in these seals, as do the newer circuit elements such as vacuum capacitors, which must carry many amperes of circulating current in tuned tank circuits. Higher plate voltages on power tubes and high-voltage vacuum switches, relays, and circuit breakers put greater dielectric stress on seals and envelopes alike. Thus glass-to-metal seals, while old to the glass art, are of constantly increasing importance to the radio engineer.

The basic requirements which glass and metal properties must meet for satisfactory seals in modern electrical service are:[13–16]

(1) There must be strong adhesion at the glass-metal interface. This generally involves solution by the glass of a tough adherent oxide coating formed by suitable treatment of the metal.

(2) The relative expansion coefficients must be so related that residual stresses are less than the tensile strength of the glass. In this connection, it is to be noted that the necessity of expansion matching applies over the temperature range up to the softening point of the glass. Even with properly matched expansion coefficients, glass-to-metal seals will not be free of strain unless properly heat-treated after the sealing operation is completed.[17]

Seals to specially prepared edges of ductile metals[18] preceded more recent matched expansion glass-metal combinations and are still used in many applications.

(3) The metal must be sufficiently conducting to carry the currents required in service without overheating and to permit electrical welding or other desired metal bonding operations with connected circuit elements or associated structural parts.

(4) The glass must have sufficient stability, chemical durability, electrical resistivity, and low dielectric loss at operating temperatures to avoid electrical failure either by conduction augmented by electrolysis or by thermal failure due to cumulative high-frequency heating.

Credit for fulfilling these exacting and often mutually antagonistic requirements belongs jointly to the glass technologist and metallurgist, whose co-operative research has provided the tube engineer with a wide variety of useful combinations, ranging from glasses to match cold-rolled steel at $137\times10^{-7}$ centimeter per degree centigrade, per unit length to tungsten at $45\times10^{-7}$. Details of proper procedure for making glass-to-metal seals have been published.[13–20]

Still another form of hermetic sealing of glass to metals has been developed which permits the attachment of metal parts or fittings to glass electrical bushings, by soldering to metallized glass.[21] This process is finding current application to provide hermetic seals for leads and terminals on metal cases of transformers and condensers, permanently attached windings of fixed characteristics for high-frequency coils, glass condenser electrodes, and conducting screens for high-voltage or high-frequency electric fields.

## Conclusions

The data on glass properties brought out in the preceding discussion may be summarized as follows:

(1) Surface resistivity varies with composition, temperature, and relative humidity from $10^{16}$ to $10^{7}$ ohms. With alternating-current potentials surface resistivity decreases as frequency increases.

(2) Volume resistivity at room temperature varies from $10^{19}$ to $10^{8}$ ohm centimeters with glass composition. As temperature increases to the melting point all glasses become electrically conducting molten electrolytes with resistivities of a few ohms or less.

(3) Dielectric constant in direct-current fields varies with time of charge. In alternating-current fields the dielectric constant of glass varies from less than 4 to over 16.

(4) Power factor of glass varies from 0.05 per cent or less for good borosilicate electrical glass to several per cent for alkali glasses.

(5) Loss factor varies from 0.0021 for low-loss electrical borosilicates at radio frequencies to over 50 for alkali-lime glass at 60 cycles.

(6) Dielectric strength is very high when edge effect and breakdown of the ambient medium are eliminated by proper design.

(7) Special forms of electrical glass of recent development which are finding wide application in insulation problems include (1) fiber-glass tapes, braided sleeving, cordage, laminated products, electrical cloth and mica combinations, (2) multiform glass parts of intricate shape and accurate dimensions, (3) VYCOR Brand 96 per cent silica glass products in clear form and multiform, and (4) a wide variety of glass-to-metal seal combinations including metallized glass for soldered bushing and terminal connections, and permanently fixed coil windings and electrodes.

[13] H. Scott, "Recent development in metal sealing into glass," *Jour. Frank. Inst.*, vol. 220, pp. 733–753; December, 1935.

[14] A. W. Hull and E. E. Burger, "Glass-to-metal seals," *Physics*, vol. 5, pp. 384–411; December, 1934.

[15] W. E. Kingston, "Low expansion alloys for glass-to-metal seals," *Trans. Amer. Soc. Metals*, vol. 30, pp. 47–67; March, 1942.

[16] A. W. Hull, E. E. Burger, and L. Navias, "Glass-to-metal seals II," *Jour. Appl. Phys.*, vol. 12, pp. 698–707; September, 1941.

[17] J. T. Littleton, "The effect of temperature treatment on glass-to-metal seals," *Jour. Amer. Ceramic Soc.*, vol. 18, pp. 239–245; August, 1935.

[18] W. G. Houskeeper, "The art of sealing base metals to glass," *Trans. A.I.E.E.* (*Elec. Eng.*, vol. 42, June, 1923), vol. 42, pp. 870–877; June, 1923.

[19] J. Strong and Collaborators, "Procedures in Experimental Physics," Prentice-Hall, Inc., New York, N. Y., 1938, chapter 1.

[20] Corning Glass Works Publication, "Laboratory Glass Blowing with Pyrex Brand Glass," pp. 17–18; 1938.

[21] D. E. Newton, "Methods of hermetic sealing," Part I, *FM Radio Electronics*, vol. 3, pp. 22–25; June, 1943; Part II, vol. 3, pp. 14–16; July, 1943.

# The Design of an Intermediate-Frequency System for Frequency-Modulated Receivers*

WILLIAM H. PARKER, JR.†, ASSOCIATE, I.R.E.

*Summary*—**With a possibility that the present frequency-modulation wave band may be increased in width it has become imperative that an intermediate-frequency amplifier operating at a frequency higher than that most commonly in use at present, 4.3 megacycles, be developed. Stability both as to performance and permanence of adjustment govern the choice of frequency and restrict this choice to a definite maximum value. Design data are given in this paper for an amplifier operating on 8.25 megacycles which satisfies the stability conditions, and gives the required performance.**

## Introduction

RADIO receivers designed for the reception of frequency-modulation broadcasts are usually of the superheterodyne type employing a stage of radio-frequency amplification followed by a frequency converter and with two stages of intermediate-frequency amplification preceding the limiter and frequency discriminator. The band of frequencies assigned to these transmissions, namely, 42 to 50 megacycles, dictates a value of receiver intermediate frequency somewhat greater than 4 megacycles in order to avoid image interference from other frequency-modulation transmissions. With a view to the possibility that the frequency-modulation band may be extended beyond 50 megacycles, and also with an idea of standardizing with television receiver practice, an intermediate-frequency value of 8.25 megacycles in superheterodyne receivers seems in order. This discussion is limited to the problems arising in the design of the intermediate-frequency amplifier when two stages are employed using a frequency of 8.25 megacycles, and to the transformer design problems involved in coupling a limiter to a frequency discriminator.

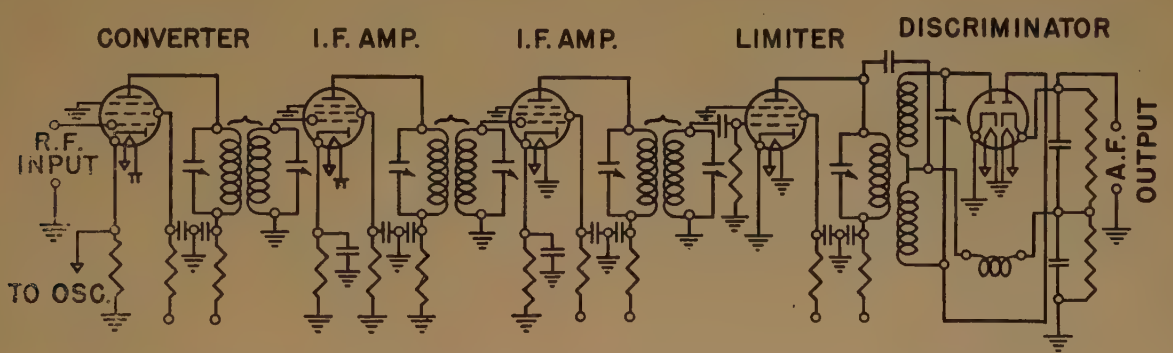


Fig. 1—Schematic for frequency-modulation—intermediate-frequency amplification.

## The Intermediate-Frequency Amplifier

The gain required in the intermediate-frequency amplifier is expressed by the ratio of the voltage needed at the limiter for effective operation (approximately 2 volts) to the voltage appearing at the input to the converter tube from an assumed 5 microvolts at the antenna terminals. The gain is of the order of 40,000 times assuming a total radio-frequency gain of 10.

As a selectivity requirement, the amplifier must allow passage of modulation frequencies to ±100 kilocycles, from the carrier with a minimum of attenuation and then must attenuate as rapidly as possible thereafter. Previous experience with 4.3 megacycles has indicated that an attenuation of 6 decibels, 75 kilocycles removed from the carrier, will result in no observable output distortion. Under this condition, an attenuation of 30 decibels at 200 kilocycles removed from tune can be achieved in design and will result, from a field standpoint, in a practical degree of selectivity. These conditions dictate the requirements for an intermediate-frequency amplifier operating at 8.25 megacycles.

Several factors govern the gain and the selectivity of the intermediate-frequency amplifier when the value of the intermediate frequency is established. These are principally (a) the mutual conductance of the amplifier tube and its interelectrode capacitance, (b) the number and $Q$ of the tuned circuits, and (c) the ratio of inductance to capacitance in the tuned circuits.

The mutual conductance of the amplifier tube enters into the gain as a first-order effect. The interelectrode capacitance (i.e., between control grid and plate) acts to limit the maximum gain by introducing regeneration effects.[1]

The gain factor of an amplifier tube may thus be considered as directly proportional to $g_m$, and inversely proportional to $C_{gp}$. Three types of tubes have been proposed for amplifier service. A comparison of their

* Decimal classification: R363.1. Original manuscript received by the Institute, July 25, 1944; revised manuscript received, September 25, 1944.

† Stromberg-Carlson Company, Rochester, New York.

[1] J. A. Worcester, Jr., "Double superheterodyne for FM receivers," *FM Magazine*, vol. 4, pp. 15–18, 58–60; March, 1944.

properties may be of interest. The superior properties of the type 6SG7 tubes are obvious and this type was accordingly selected for use in the amplifier.

TABLE I

| Tube Type | $g_m$ | $C_{gp}$ | Gain Factor |
|---|---|---|---|
| 6SK7 | 2000 | 0.003 | 667 |
| 6SG7 | 4000 | 0.003 | 1334 |
| 6AC7 | 9000 | 0.015 | 600 |

The intermediate-frequency amplifier comprises three amplifying tubes, including the converter, and three interstage transformers of double-tuned-circuit design. The schematic is shown in Fig. 1. The individual stage gain is expressed by the relation, when the coupling coefficient $k$ is at the critical value[2]

$$\text{stage gain} = g_m(w\sqrt{L_1L_2}\sqrt{Q_1Q_2})/2$$

$g_m$ = mutual conductance of the amplifying tube
$w$ = angular value of the intermediate frequency
$L_1$ = inductance of the primary circuit
$L_2$ = inductance of the secondary circuit
$Q_1$ = figure of merit of primary circuit
$Q_2$ = figure of merit of secondary circuit

By design considerations $L_1$ is made equal to $L_2$, and $Q_1$ is made equal to $Q_2$, which reduces the expression to stage gain $= g_m(wLQ/2)$.

The individual stage selectivity is a function of the circuit $Q$, and the over-all selectivity requirement previously stated is attained by using appropriate pairs of selective circuits in individual transformers. It then becomes necessary to balance the influence of $Q$ in stage gain against its effect on selectivity. The maximum antenuation requirement of 30 decibels at 200 kilocycles removed from tune resolves to an individual stage attenuation of 10 decibels. By reference to convenient data based on the attenuation as a function of the number and $Q$ of the circuits and deviation from mid-frequency, the required value of $Q$ is found[3,4] to be 45.

The ratio of inductance to capacitance chosen for the tuned circuit is a compromise between amplifier stage gain and stability. The tuning inductance should be high so as to provide adequate stage gain, but on the other hand, the tuning capacitance should be high in order to minimize the effects of changes in capacitance with temperature in the tube, the socket, and the associated wiring. Experience has indicated that not less than 35 micromicrofarads should be included in the total shunt capacitance to allow stable operation and optimum gain. At 8.25 megacycles, the circuit inductance is thus 10.5 microhenries.

The total gain requirement of 40,000 results in an individual stage-gain requirement of slightly more than 34, assuming equal gain in all stages. This is only approximately the case, since the gain in the converter and the gain in the stage preceding the limiter are less than in the normal intermediate-frequency stage. The load conditions in the converter and limiter stages are not the same as in a normal intermediate-frequency amplifier and thus a different adjustment in coupling is required in order that the desired selectivity and gain be realized. Referring to the expression for stage gain, and inserting established circuit constants, a gain of 49 is calculated for the interstage intermediate-frequency amplifier. This result was experimentally verified. By suitable adjustment of coupling, a conversion gain of 27 was realized, and in the stage preceding the limiter a gain of nearly 30 was obtained. The net over-all gain is thus computed to be 39,800 which is in close agreement with the specification.

[2] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York 18, N. Y., 1943, section 5, paragraph 19.
[3] See section 3, paragraph 5, of footnote reference 2.
[4] "Radiotron Designer's Handbook" (third edition) edited by F. Langford Smith, published by Wireless Press for Amalgamated Wireless Valve Company, Sydney, Australia, 1942, p. 128.

## The Intermediate-Frequency Transformer

Experimental work led to the development of intermediate-frequency transformers embodying the circuit constants enumerated. The data are tabulated as follows:

Coil form diameter . . . . . $\frac{5}{16}$ inch
Wire size . . . . . no. 36 B&S gauge enamel
Type of winding . . . . . solenoid, single layer
Number of turns (primary) . . . . . 32
Number of turns (secondary) . . . . . 32
Distance between inside turns of windings . . 23/64 inch
Shield container . . . . . $1\frac{3}{8}$ inches square on sides
$Q$ of windings, in air . . . . . 75

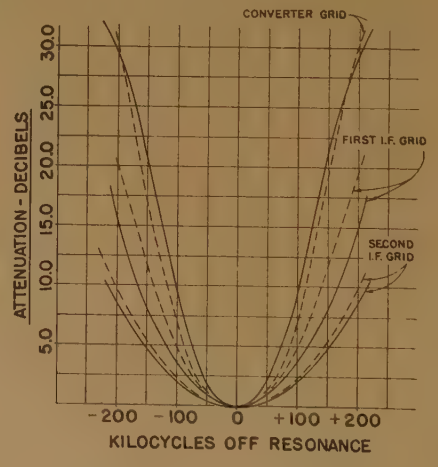


Fig. 2—Selectivity characteristic 8.25-megacycle intermediate-frequency amplifier.

The measured gain of the first intermediate-frequency stage with the transformer described was 55, and that of the second stage (operating into the limiter) was 31. The selectivity characteristics of one, two, and three stages, both calculated and measured are shown in Fig. 2. The selectivity is measured between the second intermediate-frequency-amplifier grid and the limiter input, between the first intermediate-frequency-amplifier grid and the limiter input, and between the converter grid and the limiter input as indicated.

A word might be said as to the need for electrostatic shielding between transformer windings. In the absence of a shield, the capacitive coupling in the design

described is approximately the same order of magnitude as the inductive coupling. Capacitive coupling makes difficult the attainment of a symmetrical selectivity curve. Also effective coupling between the windings

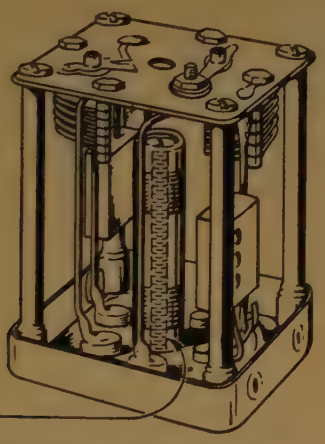


Fig. 3—Intermediate-frequency transformer, 8.25 megacycles.

changes rapidly with spacing and the desired coupling is difficult to obtain and to maintain in production. The simple expedient of a brass screw inserted axially in the coil and connected to a frame proved a satisfactory means of minimizing the disturbing electrostatic coupling. A typical transformer construction is shown in Fig. 3.

### The Discriminator Transformer

Derivation of the audio voltage from the frequency-modulated signal is accomplished in the discriminator network following the limiter. Due to its simplicity and ease of adjustment, the well-known Foster-Seeley circuit is used. A transformer for this service was designed. Its specifications follow:

Coil-form diameter.....¼ inch
Wire size (primary and secondary).....
.....no. 38 B&S gauge single silk enamel
Type winding (primary).....universal (64/66 gears)
Type winding (secondary).....solenoid, single layer
Number of turns (primary).....35
Number of turns (secondary).....58
Shield container.....1⅜ inches square on sides
$Q$ of primary in air.....35
$Q$ of secondary in air.....65

The voltage-input versus output-frequency change is shown in Fig. 4. These data were obtained by intro-

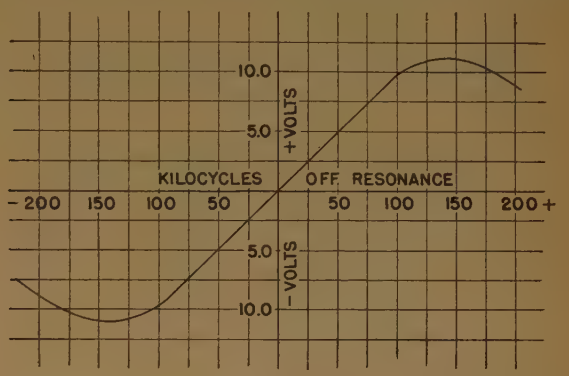


Fig. 4—Discriminator characteristic, 8.25 megacycles.

ducing a frequency-modulated source at the limiter grid and observing the direct-current change in the discriminator output as the modulation index was changed. A carrier level of 2 volts input was used. The characteristic is observed to be linear to ±75 kilocycles from the center frequency, with some departure from linearity between ±75 to 100 kilocycles from the center frequency.

### Conclusion

The intermediate-frequency amplifier of the design described was installed in several experimental receivers previously designed for 4.3-megacycle operation. Satisfactory results were obtained. The receivers were uniform in performance, and indications are that no difficulties due to instability will arise when the receivers are built in production.

# Triode Linear Saw-Tooth-Current Oscillator*

LEONARD R. MALLING†, Associate, I.R.E.

*Summary*—**It is shown that a triode may be used for generating a linear saw-tooth current when coupled to a suitably designed transformer. The triode is operated on a hitherto unused portion of the $E_p/I_p$ characteristics, notably the positive-grid region where the $E_p/I_p$ characteristic is a straight line of slope $R=E_p/I_p$. While the over-all efficiency of the oscillator is low, it is shown to be inherently more efficient than conventional scanning systems operating in the negative-grid region. Improved operating conditions and circuit efficiency may be obtained by the use of an inverted diode. The losses in a typical triode-scanning oscillator are analyzed and individually computed for a given design. Attention to these individual circuit losses should enable designs to be made of considerably higher efficiency.**

* Decimal classification: R355.9. Original manuscript received by the Institute, February 23, 1944; revised manuscript received, July 24, 1944; revised manuscript received, September 25, 1944.
† 127 Argyle Pl., Seattle 3, Washington.

MANY diverse methods are used for the generation of saw-tooth currents for sweeping cathode-ray tubes. It is not generally realized, however, that a triode vacuum tube using a suitably designed magnetic and electric circuit is capable of producing a linear sweep with a high degree of efficiency and simplicity of circuit design. Like the triode sine-wave oscillator, the frequency and wave-form characteristics are almost completely determined by the feedback transformer design. The use of the triode oscillator for magnetic scanning was first proposed by Philo T. Farnsworth,[1] modifications being made later by other workers in the field, notably G. R. Tingley and A. H. Gilbert.

[1] U. S. Patent No. 2,059,683, November 3, 1936.

The salient design features that affect linearity and efficiency will be discussed in detail with an analysis of the tube operation.

## Description of Basic Circuit

Fig. 1 shows the basic circuit of the triode saw-tooth-current generator. The ratio of $L/C$ is high and the two windings of the transformer are tightly coupled on a closed iron core. Oscillations in circuits of this type were first discussed in a paper by Vecchiacci[2] who presented oscillograms showing that while the plate and grid voltages would exhibit pulse characteristics the plate

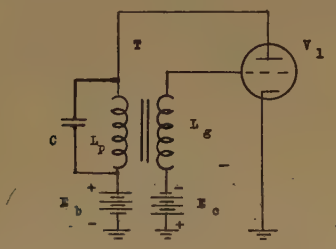


Fig. 1—Basic saw-tooth current-generator circuit.

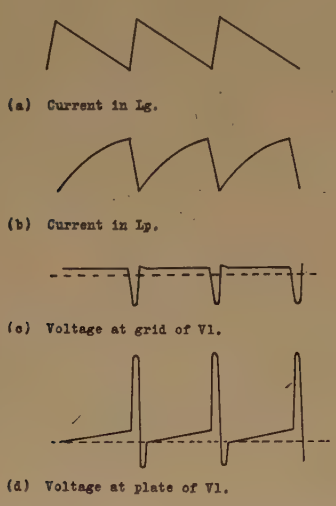


Fig. 2—Current and voltage wave forms in circuit of Fig. 1.

and grid currents would be of substantially saw-tooth wave form. Operation of this class of oscillator is characterized by two modes of oscillation, a vigorous single sine-wave-voltage oscillation of frequency given by $|\omega^2| = 1/LC$ followed by a period of heavy grid current lasting several such cycles during which these voltage oscillations are effectively damped out and a saw-tooth current generated. The length of this damped period which fixes the frequency of the saw-tooth current oscillations is determined chiefly by the transformer design but is also influenced by the applied bias. The sine-wave-voltage oscillation frequency is determined entirely by the $LC$ product of the circuit components. These two modes of oscillation are illustrated in Fig. 2 which gives the voltage and current waveforms existing in the basic circuit.

Fig. 3, an equivalent of circuit for Fig. 1, shows the manner in which the vacuum tube acting as a switch changes from the heavily damped period $t_1$ to the short oscillatory period $t_2$. When the switches are closed $C$ is quickly charged and a high current established in $R_g$. Then, as current is gradually established in $L_p$, the voltage across it drops, and the current in $R_g$ drops. If $L_p$ is replaced by a two-winding transformer, $I_p$ starts as the reflected $I_g$ and increases. $I_g$ starts as some high

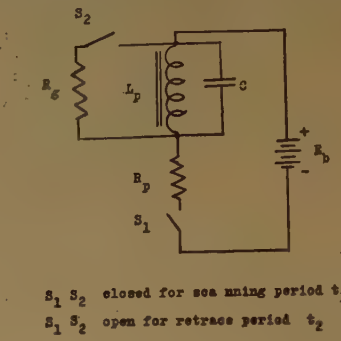


Fig. 3—Equivalent circuit for saw-tooth-current oscillator.

value and decreases. The period $t_1$ may be considered as a long direct-current charging period in which the plate current increases exponentially through the inductance $L_p$ which will induce a similar current in $L_g$. However, owing to the grid-current characteristics of the vacuum tube, the current in $L_g$ does not follow exactly the plate-current variations. Assuming for the moment a linearly falling current in $L_g$ a steady positive potential $e_g$ will be induced across $L_g$ given by

$$e_g = -L_g(di_g/dt). \qquad (1)$$

The bias is set so that this voltage drives the tube into the positive-grid region for the whole of the scanning period $t_1$. The $I_p/E_p$ characteristics of a typical triode operating in the positive-grid region are shown in Fig. 4

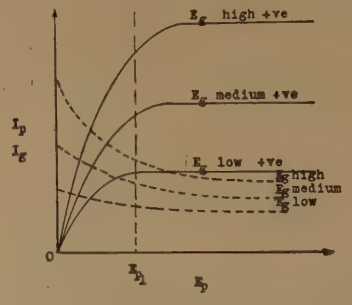


Fig. 4—Plate-current—plate-voltage and grid-current characteristics for the positive-grid region.

and the operating region that is of interest for our purpose lies between zero plate voltage and the voltage indicated by the dotted line $E_{p_1}$ representing a scanning-time excursion $t_1$. Over this part of the characteristic the tube is acting substantially as a pure resistance with an equation of the type $R_p = E_p/I_p$ being satisfied. The plate and grid impedance will be of the order of a few hundred ohms for triodes of the power-output class. However, it will be noted that the grid impedance given by

$$r_g = \partial e_g/\partial i_g \qquad (2)$$

changes markedly over the working region defined, so

[2] F. Vecchiacci, "Oscillations in the circuit of a strongly damped triode," Proc. I.R.E., vol. 19, pp. 856–873; May, 1931.

that as $I_p$ rises $r_g$ rises and thus accelerates the falling off of the grid current. By suitable choice of circuit parameters the current in $L_g$ can be made to decrease linearly. The effect of grid loading on $I_g$ is shown in Fig. 5.

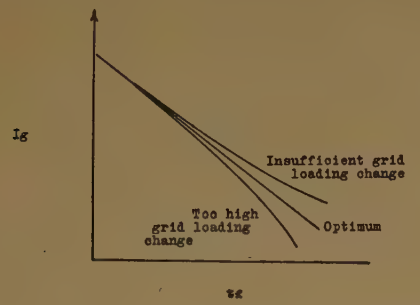


Fig. 5—Effect of variable-grid loading on secondary current in transformer.

## Application of Triode Oscillator to Scanning Problems

In order to utilize the saw-tooth current existing in the transformer windings, some form of magnetic circuit is required to enclose the cathode-ray tube neck. The leakage flux may be used direct as shown in Figs. 6a and 6b, or separate scanning coils may be used as shown in Fig. 6c. A typical triode-oscillator circuit designed for high-scanning frequencies is shown in Fig. 7 and functions in general like the basic circuit of Fig. 1 except that the diode rectifier modifies the behavior of the voltage oscillation and separate scanning coils are used. The capacitance $C$ of Fig. 1 now becomes the sum of the tube and stray capacitances, making the $L/C$ ratio as high as is practically possible. The negative-plate excursion of Fig. 2(d) is now eliminated by the diode as when the plate swings negative the diode draws current thus charging the capacitance $C$. The energy so obtained is available for conversion into the magnetic field of the scanning coils, see Fig. 8. The energy relation is given by

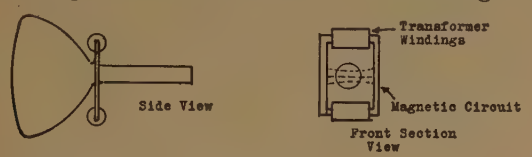


Fig.6a. Magnetic Circuit using Closed Yoke.

Fig.6b. Magnetic Circuit using Open Yoke.

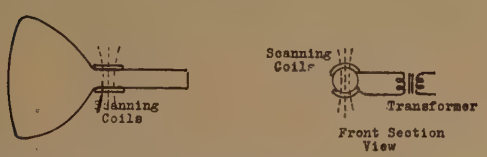


Fig 6c. Use of Separate Scanning Coils.

Fig. 6—Types of magnetic circuit for use with cathode-ray tube.

$$W_c = 1/2\ CE_c^2 \text{ joules} \quad (3)$$

where

$$E_c = -L_s(di_s/dt) \quad (4)$$

and $L_s$ is the scanning-coil inductance and $i_s$ the scanning-coil current. Heater current for the diode may be taken direct from the scanning transformer when the heater-power requirements are low. Negative bias to the triode is supplied by the direct-current drop in the variable resistor $R_1$ which is by-passed for scanning currents. The resistor $R_2$ is used for control of scan amplitude. Fine control of scanning frequency is obtained by adjustment of $R_1$. Increased bias decreases the excursion into the positive-grid region shortening the time over which the plate-current swing is linear and decreasing the linear charging period $t_1$. This gives a higher scanning frequency and vice versa. The retrace time will remain constant, being controlled entirely by the $LC$ components so that the percentage retrace time will vary with scanning frequency. Synchronization is best accomplished by coupling direct to the grid through a diode and using a negative synchronizing pulse. By connecting the diode plate direct to the grid negative synchronizing pulses pass to the grid but negative oscillation potentials are prevented from passing back into the synchronizing circuits. In cases where precise timing is not important a third winding may be added to the transformer and coupled in the plate circuit of the synchronizing tube in such phase as to give the required negative synchronizing pulse at the grid of the triode.

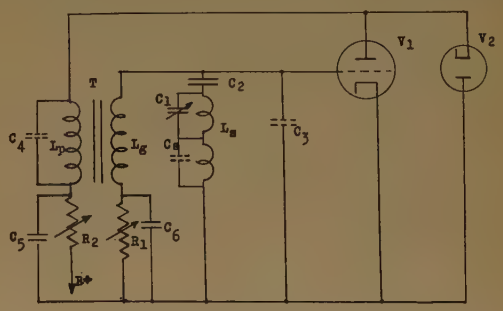


Fig. 7—Schematic diagram of typical scan oscillator designed for high scan frequency.

$C_1$ added capacitor to balance $C_s$
$C_2$ coil coupling
$C_3$, $C_4$ stray capacitance
$C_5$, $C_6$ by-pass capacitors
$L_s$ scanning coils
$R_1$ scan-frequency control
$R_2$ scan-amplitude control

An attempt is made in the following brief analysis of circuit losses to show how power is dissipated in the various circuit components and the relation that these circuit losses have to the power actually used for scanning. The losses and efficiency of the circuit of Fig. 7 may be conveniently analyzed by means of the equivalent circuit diagram of Fig. 9. The effective load on the

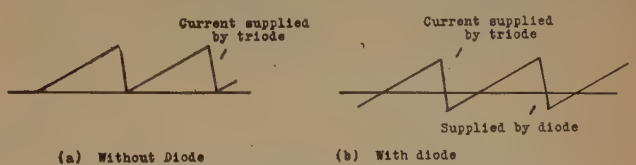


Fig. 8—Part of the scanning current is supplied by efficiency diode of Fig. 7.

oscillator will be the grid resistance of the vacuum tube, and it is this load which is the effective plate load of the oscillator tube when considering power relationships. The scanning coils may be considered as a factor affecting the power factor only when considering total losses. For constant grid voltage and zero leakage reactance in the transformer maximum power into $r_g$ will be delivered by the generator of Fig. 9 when $r_p = r_g$, $X_{L_s}$ and $X_c$ being assumed high. However, the leakage inductance $L_e$ modifies this relationship so that maximum power would be delivered when $r_g = X_{L_e}$. The leakage reactance is usually sufficiently high to prevent the latter from being realized as too high a transformer ratio would be required making the effective $C$ too high. The ratio should also be kept low so that the ratio of leakage

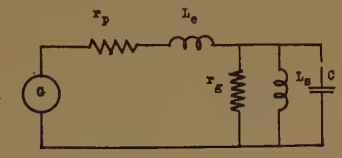


Fig. 9—Equivalent circuit for high scanning frequency. 1:1 transformer ratio assumed.

reactance to coil inductance $L_s$ is low in order to minimize loss of the reactive scanning power.

The ratio of the current in the load without matching to the load current with perfect matching is given by

$$k = \frac{[4r_p/(r_g + jX_{L_e})]^{1/2}}{1 + [r_p/(r_g + jX_{L_e})]}. \tag{5}$$

Some knowledge of the circuit constants is necessary to determine the losses and the circuit efficiency. The scanning-coil inductance is given by

$$L_s = 1/\omega_0^2 C \text{ henries} \tag{6}$$

where $\omega_0$ is given by

$$f_0 = 1/2t_2 \tag{7}$$

and $t_2$ is in seconds.

The field intensity required to deflect the beam through half the total scanning angle is given by

$$H = 3.36V^{1/2} \sin \beta/l_c \text{ gauss} \tag{8}$$

where $\beta$ is the half-scan angle, $V$ the second anode potential, and $l_c$ the coil length.

The ampere-turns required in the scanning coils to produce this field

$$NI_s = (1/0.4\pi)Bl_g. \tag{9}$$

$B = H$ for this particular case where the field is in air.

The mean length of the gap

$$l_g = \pi d/4 \text{ approximately} \tag{10}$$

where $d$ is the over-all diameter of the cathode-ray tube neck. Knowing the number of turns in the coil enables the coil current to be determined and allowing for the transformer ratio the peak tube plate current can be found

$$I_{L_p} = I_s/n. \tag{11}$$

The positive-grid potential to give a linear relation $E_p/I_p$ over this plate-current range can be found from the tube characteristics.

The over-all efficiency of a scanning system may be defined as the ratio of the power required to sweep the beam to the input power delivered to the scanning system. The energy required to sweep the beam in one direction per cycle

$$W_s = (1/2)L_s I_s^2 \tag{12}$$

where $I_s$ = root-mean-square saw-tooth current and $I_{rms} = I_{max}/\sqrt{3}$. The power used for creating the magnetic field at a frequency $f_s$ is given by

$$P_s = f_s W_s \text{ watts.} \tag{13}$$

The input power to the system is of course given by the product $E_b I_p$ direct current and the difference between this figure and that given by (13) represents the losses. These losses may be broken down into those introduced by the transformer, tube losses, and mismatch losses.

At low frequencies the transformer losses in a scanning system are mostly copper losses and at high frequencies mostly iron losses. The core loss is the sum of the eddy current and hysteresis losses $W_c = W_e + W_h = K_h f_s + K_e f_s^2$ where $K_h$ and $K_e$ are hysteresis and eddy-current factors dependent on the iron used. The eddy current losses $W_e = (\pi^2/6\rho)b^2 f_s^2 B_{max}^2 10^{-14}$ watts per cubic centimeter and the hysteresis losses $W_h = n f_s B_{max}^{1.6} 10^{-7}$ watt per cubic centimeter where $t$ = thickness of laminations meters, $B_{max}$ gauss, $\rho$ = ohmmeters, $n$ = a constant, which for silicon steel may be taken as 0.001. A useful approximation for the core losses may also be made by extrapolation of the manufacturer's curves given for lower frequencies.

The tube losses are the plate loss

$$W_p = (I_{max}^2/3)R_p \tag{14}$$

and the grid loss

$$W_g = I_{sv}^2 R_g. \tag{15}$$

The mismatch losses are given by (5).

## Practical Design

A preliminary series of approximations will be made on a typical design to indicate the nature of the problem involved and the magnitude of the various losses. The data are shown in Table I.

TABLE I

| | |
|---|---|
| Scanning frequency | 15,000 cycles per second, 10 per cent retrace time |
| Cathode-ray tube | 7 CP1 |
| Triode oscillator tube | 6L6 triode-connected |
| Second anode potential | 7000 volts |
| Length of trace | 6 inches |
| Scanning-coil length | 2 inches |
| Scan transformer | 1.4-to-1 ratio, cross-section area 1 square inch, core length 5½ inches |

The circuit to be used will be identical with that shown in Fig. 7.

The energy required to sweep the beam at 15,000 cycles per second will first be determined. To do this the scanning-coil inductance and the root-mean-square saw-tooth current flowing in the coils must be evaluated. The frequency of the free oscillation period $f_0 = 75$ kilocycles from (7) and assuming $C = 100$ micromicrofarads the scanning-coil inductance $L_s = 45$ millihenries from

(6). The scanning-coil current can be determined from a knowledge of the magnetic scanning field and the turns comprising the scanning coils. From handbook data on the 7 CP1 and the length of trace given above, the half-scan angle becomes 23 degrees for a radius of deflection of 7 inches. Thus from (8) $H=21.6$ gauss, or the total field required for full sweep is 43.2 gauss. From (9) and (10) 95 ampere turns are required in the scanning coils for creating this field of 43.2 gauss. Assuming simple square scanning coils of square cross section bent to fit the tube neck and surrounded by a thin circular iron shield the total number of turns may be estimated at 740. This gives a peak current of 128 milliamperes or a root-mean-square saw-tooth current of 74 milliamperes. Thus from (12) the energy required to sweep the beam $W_s=124$ microjoules and the power used for creating the field at a frequency of 15,000 cycles is 1.86 watts from (13).

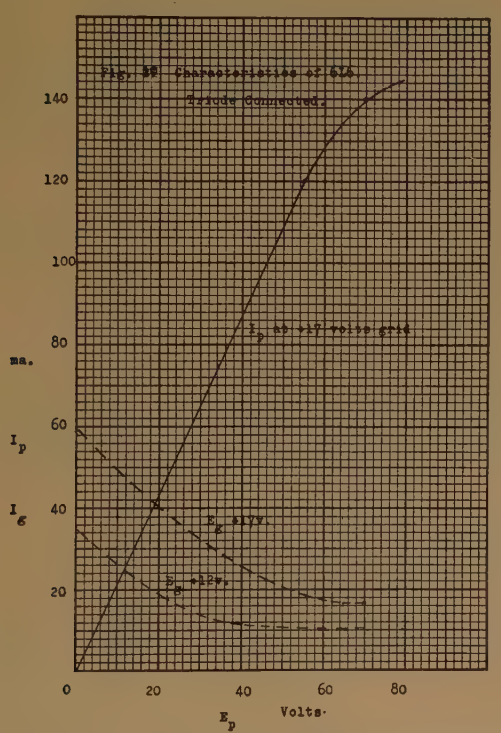


Fig. 10—Characteristics of 6L6. Triode connected. Positive bias.

It will be of interest to see how much of the energy required to sweep the beam is supplied by the diode. From (4) the voltage developed across the scan coils $E_c=860$ volts so that the energy stored $W_c=37$ microjoules or 30 per cent of the total scanning-power requirements.

The correct operating characteristics for the oscillator tube may now be considered. The peak current flowing in the primary or plate winding of the transformer allowing for the 1.4-to-1 transformer ratio will be 92 milliamperes. The positive bias required to obtain a substantially linear $I_p/E_p$ relationship up to this current for the 6L6 is of the order of 17 volts, and Fig. 10 shows an $E_p/I_p$ curve for the 6L6 with these conditions. Corresponding grid-current curves are also shown. From these curves it can be seen that $R_p=470$ ohms and that the grid resistance varies from 200 to 400 ohms.

Some estimate of the leakage inductance must be made before the total losses are calculated and a brief outline of a typical scan transformer will be of interest in this connection. The grid inductance of the transformer should be several times that of the scanning coils to avoid shunting effects, say 0.45 henry so that the plate inductance will be 0.9 henry. A preliminary approximation for the number of turns required on a 1-inch square core to give the required inductance of 0.9 henry gives 800 turns. This may be checked by determining the inductance given by this number of turns when carrying the direct plate current and saw-tooth current. The direct plate current will be of the order of 70 milliamperes so that the polarizing magnetomotive force $H_0=5$ gilberts per centimeter ($l=14$ centimeters) giving an incremental permeability of 400 for standard audio $A$ laminations. The flux density $B_{\max}=(E_{\text{rms}}10^8)/(4.44f_sN_pAK_A)$. Now $E_{\text{rms}}=E_{\max}(t_1/t_1+t_2)^{1/2}=380$ volts. $E_{\max}=1.4\times860$, the grid voltage times the transformer ratio. So that $B_{\max}=125$ gauss. The plate inductance calculates out to be close to the required figure of 0.9 henry with this flux density. Using suitable formulas[3] the leakage inductance may be determined and may be approximated at 55 millihenries.

The separate losses may now be calculated and summed. The mismatch loss due to the leakage reactance will be figured for best match at the highest working grid impedance which is 400 ohms. The plate resistance is 470 ohms and the load impedance is the sum of the grid resistance and the leakage reactance, that is 5200 ohms, so that from (5) $k=0.55$ giving a loss of 5 decibels or a power loss ratio of 3.16. The power loss at the grid $E^2/R_g$ is 1 watt, where $E$ is the positive grid voltage developed at the grid during the scanning time. The plate power loss is $I_{\text{rms}}{}^2r_p$ giving a figure of 2.5 watts. Losses in the grid resistor can be determined from the difference between the positive grid voltage developed and the positive bias required for correct grid operation. The positive bias developed by the flow of saw-tooth current through the grid inductance is 96 volts and the required fixed grid potential is 17 volts positive. From the tube characteristics the average direct current is 40 milliamperes and thus the grid resistor power loss is 3.75 watts. Summing the above it can be seen that the total plate power required to drive the grid circuit will be 12 watts. Core losses calculate out at 2 watts and extrapolated data give 3 watts, but experience indicates a figure of from 3 to 4 watts for a scanning frequency of 15 kilocycles. The total of these losses gives a figure of 18 watts, and as the power required to sweep the beam in one direction is of the order of 1.8 watts the over-all efficiency of the scanning oscillator is 10 per cent.

[3] Harold Pender and Knox McIlwain, "Electrical Engineers' Handbook," vol. 5, John Wiley and Sons, New York, N. Y., 1936, section 5 to 21.

# Impulse Excitation of a Cascade of Series Tuned Circuits*

SAMUEL SABAROFF†, ASSOCIATE, I.R.E.

*Summary*—**The response of a cascade of series tuned circuits to an impulse is mathematically determined. The peak value of this response is examined and found to be approximately $E=SG(\omega_2-\omega_1)/2$ where $S$=impulse strength, $G$=network gain at the resonant frequency $\omega_1$ and $(\omega_2-\omega_1)$ is the bandwidth at 0.707 down on the voltage characteristic. This peak value is relatively independent of the number of tuned circuits when $5<n<Q/2$ where $n$=number of tuned circuits and $Q=\omega L/R$.**

THE elementary noise is that resulting from a single impulse. All other noises may be considered to be the result of combinations of such impulses. Radio devices in which noise manifests itself are usually composed of cascaded tuned circuits. An analysis of the response of a network composed of a cascade of simple series-resonant circuits to an impulse is therefore fundamental in the study and measurement of noise.

The noiselike qualities of the network response to an impulse is determined in large part by the peak[1] value of this response. Variation in the shape of an impulse has relatively little effect provided its duration is small with respect to the natural period of the excited circuit.[2]

It has been stated and experimentally verified that the peak value of the network response to an impulse is proportional to the effective over-all bandwidth.[3] The following mathematical analysis formally verifies this fact subject to certain conditions.

The differential equation of a simple series-resonant circuit in terms of the condenser voltage is

$$LC(d^2v_1/dt^2)+RC(dv_1/dt)+v_1=V \tag{1}$$

where $V$=applied voltage.

Assuming an initial condition of equilibrium,[4-6] the Laplacian solution of (1) is

$$\bar{v}_1=\overline{V}/(LCp^2+RCp+1) \tag{2}$$

where the bar indicates the operation of multiplying by $e^{-pt}$ and taking the infinite integral with respect to $t$.

For example

$$\bar{x}=\int_0^\infty e^{-pt}x(t)dt \tag{3}$$

where $|p|>0$.

The network is assumed to be a cascade of simple series-resonant circuits as shown in Fig. 1, with the voltage across the condenser of each circuit taken to be the driving force for the next. The reaction of each circuit on the preceding one is taken to be zero.

The Laplacian solution for the voltage across the condenser in the $n$th circuit is then

$$\bar{v}_n=\overline{V}/(LCp^2+RCp+1)^n. \tag{4}$$

Equation (4) may be written

$$\bar{v}_n=\overline{V}/\{(LC)^n[(p+\alpha)^2+\beta^2]^n\} \tag{5}$$

where $\alpha=R/(2L)$ and $\beta=\sqrt{(1/LC)-R^2/(4L^2)}$.

Equation (5) is a formal solution with no restrictions other than those required by Laplacian theory.

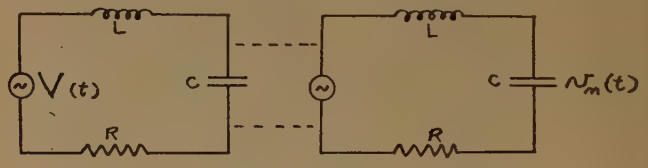


Fig. 1—Cascaded series-resonant circuits.

The driving force is taken to be an impulse occurring at $t=+0$. The Laplacian of such an impulse is a constant called the strength of the impulse; thus

$$\overline{V}=S \tag{6}$$

where $S$ is the impulse strength.

Equation (5) now can be written

$$(LC)^n\bar{v}_n/S=[(p+\alpha)^2+\beta^2]^{-n}. \tag{7}$$

Equation (7) may be solved without great difficulty for $v_n(t)$ by purely mathematical means. However, various Laplacians and their inverses have been tabulated. The more practical method would be to peruse these tabulated forms for a possible solution. First, however, (7) can be somewhat simplified by applying the principle of translation,

$$(LC)^n\overline{[e^{\alpha t}v_n(t)]}/S=(p^2+\beta^2)^{-n}. \tag{8}$$

The right-hand side of (8) and its inverse have been tabulated.[7] They are

$$\frac{\sqrt{\pi}}{\Gamma(n)(2\beta)^{n-1/2}}\overline{[t^{n-1/2}J_{n-1/2}(\beta t)]}=(p^2+\beta^2)^{-n} \tag{9}$$

where $n>0$, and $J_{n-1/2}(\beta t)$ is a Bessel function of the first kind.

Equating (9) and (10), removing the bars and solving for $v_n(t)$ results in the complete solution

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† WCAU Broadcasting Company, Philadelphia, Pennsylvania. This work was done for Lucian Laboratories, Lansdowne, Pennsylvania, for whom the author was consultant.

[1] C. M. Burrill, "Progress in the development of instruments for measuring radio noise," PROC. I.R.E., vol. 29, pp. 433–441; August, 1941.

[2] John R. Morecroft, "Principles of Radio Communication," John Wiley and Sons, Inc., New York, N. Y., 1927, chapter 3.

[3] V. D. Landon, "A study of the characteristics of noise," PROC. I.R.E., vol. 24, pp. 1514–1521; November, 1936.

[4] H. S. Carslaw and J. C. Jaeger, "Operational Methods in Applied Mathematics," Oxford University Press, London, England, 1943.

[5] Murray F. Gardner and John L. Barnes, "Transients in Linear Systems," vol. 1, John Wiley and Sons, Inc., New York, N. Y., 1942.

[6] R. V. Churchill, "Modern Operational Mathematics in Engineering," McGraw-Hill Book Company, New York 18, N. Y., 1944.

[7] See transform 57 on page 298 of footnote reference 6.

$$v_n(t) = \frac{St^{n-1}e^{-\alpha t}}{(LC\beta)^n 2^{n-1}\Gamma(n)}\sqrt{\frac{\pi\beta t}{2}}\,J_{n-1/2}(\beta t). \quad (10)$$

$\beta$ may be real, zero, or imaginary, depending on whether the circuits are oscillatory, critically damped, or aperiodic. We will here consider real values of $\beta$ only.

The Bessel function in (10) may be written in terms of circular functions[8] thus lending itself to more evident analysis;

$$\sqrt{\pi\beta t/2}\,J_{n-1/2}(\beta t) = P_n(\beta t)\cos(\beta t - (n\pi/2)) - Q_n(\beta t)\sin(\beta t - (n\pi/2)) \quad (11)$$

where $n$ is an integer and

$$\left.\begin{aligned} P_n(\beta t) &= \sum_{r=0}^{\infty} \frac{(-1)^r \,\underline{|\, n-1+2r}}{\underline{|\, 2r}\;\underline{|\, n-1-2r}\,(2\beta t)^{2r}} \\ Q_n(\beta t) &= \sum_{r=0}^{\infty} \frac{(-1)^r \,\underline{|\, n+2r}}{\underline{|\, 2r+1}\;\underline{|\, n-2r-2}\,(2\beta t)^{2r+1}} \end{aligned}\right\}. \quad (12)$$

$P_n$ and $Q_n$ are terminating series, since for sufficiently large values of $r$, the factorial of a negative integer appears in the denominator and such a factorial is equal to infinity.

As a first approximation for values of $\beta t > n^2$, it will be sufficient to consider only the leading terms in (12). Making these substitutions in (10) gives

$$v_n(t) = \frac{St^{n-1}e^{-\alpha t}}{(LC\beta)^n 2^{n-1}\,\underline{|\, n-1}}\left[\cos\left(\beta t - \frac{n\pi}{2}\right) - \frac{n(n-1)}{2\beta t}\sin\left(\beta t - \frac{n\pi}{2}\right)\right]. \quad (13)$$

Let us now assume the circuits sufficiently oscillatory as to make $\alpha \ll \beta$. The value of $\beta$ then approaches the fundamental resonant frequency of the circuits, which we shall call $\omega$. Thus

$$\beta \cong \omega = 1/\sqrt{LC}. \quad (14)$$

Equation (13) may now be written, approximately

$$v_n(t) = \frac{S\omega^n t^{n-1}e^{-\alpha t}}{2^{n-1}\,\underline{|\, n-1}}\left[1 + \frac{n^2(n-1)^2}{8(\omega t)^2}\right]\cos\left[\omega t - r - \frac{n\pi}{2}\right] \quad (15)$$

where

$$\sin(r) \cong -n(n-1)/(2\omega t)$$
$$\cos(r) \cong 1 - n^2(n-1)^2/(8\omega^2 t^2).$$

Examination of (15) shows that it represents a sinusoid of varying amplitude and phase. We shall consider in some detail the amplitude characteristics only. The peak value of this sinusoid may be found by differentiating the amplitude with respect to time and equating to zero, thus discovering the necessary conditions. Substantial simplification occurs when it is remembered that the assumption of $\omega t > n^2$ has been made. Let us now specify that the change in amplitude due to the quadrature component be less than 1 per cent; i.e.,

$$n^2(n-1)^2/(8\omega^2 t^2) < 1/100. \quad (16)$$

We may, therefore, omit this term in (15) without substantial error, provided the conditions for the peak value satisfy the above inequality.

Differentiating the remaining time functions in the amplitude and then equating to zero gives

$$d(t^{n-1}e^{-\alpha t})/(dt) = 0 \quad \text{when} \quad t = (n-1)/\alpha. \quad (17)$$

Substituting the condition of (17) into (16) results in the inequality

$$n\alpha/(2\sqrt{2}\,\omega) < 1/10. \quad (18)$$

Putting $R/(2L)$ for $\alpha$, and $Q$ for $L\omega/R$ in (18) gives finally $n < 0.566Q$, or rounding off

$$n < Q/2 \quad (19)$$

as the relation to be satisfied for the quadrature component to be negligible in the region of the peak value and for times thereafter. This condition exists in most practical circuits. For these circumstances (15) becomes

$$v_n(t) = \frac{S\omega^n t^{n-1}e^{-\alpha t}}{2^{n-1}\,\underline{|\, n-1}}\cos\left(\omega t - \frac{n\pi}{2}\right). \quad (20)$$

Recourse must be had to (10) or (11) if accurate values of $v_n(t)$ are desired for times less than that at which the maximum value occurs or when the inequality of (19) is not observed.[9]

If we let $E$ be the peak value of (20), then utilizing the condition of (17), we have

$$E = \frac{S\omega^n(n-1)^{n-1}e^{-(n-1)}}{(2\alpha)^{n-1}\,\underline{|\, n-1}}. \quad (21)$$

For large values of $n$, (21) may be simplified by utilizing the Stirling approximation for the factorial

$$\underline{|\, n-1} = (n-1)^{n-1}e^{-(n-1)}\sqrt{2\pi(n-1)} \quad (22)$$

becoming thereby

$$E = S\omega^n/[(2\alpha)^{n-1}\sqrt{2\pi(n-1)}]. \quad (23)$$

The Stirling approximation is 2 per cent low for $n=6$ and 1 per cent low for $n=10$, becoming more accurate with increasing values of $n$.

Equation (23) may be further simplified by putting in the value for $\alpha$,

$$E = SRG/[L\sqrt{2\pi(n-1)}] \quad (24)$$

where $G$ is the total gain of the network $=(\omega L/R)^n$. The value of $G$ can also include any linear external amplification that may be present between the various circuits.

Equation (24) is now in terms of easily measurable quantities. The response of the network to a sine wave of frequency $\omega$ will determine the value of $G$. $R/L$ can be determined by measuring the $Q$ of one circuit. In this case (24) is

$$E = \omega SG/[Q\sqrt{2\pi(n-1)}]. \quad (25)$$

It may be more convenient to determine the ratio $R/L$ by noting a relation between the attenuation and frequency of the whole network. It can be shown that for $\alpha \ll \omega$,

[8] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand Company, Inc., New York, N. Y., 1943, pp. 51–52.

[9] E. Jahnke and F. Emde, "Tables of Functions," B. G. Teubner, Leipzig and Berlin, Germany, 1933, pp. 222–227.

$$R/L = (\omega_2 - \omega_1)/\sqrt{A^{2/n} - 1} \quad (26)$$

where $(\omega_2 - \omega_1)$ is the bandwidth at a point on the voltage characteristic that has a relative attenuation of $A$, with the minimum attenuation taken as unity.

Incorporation of (26) in (24) gives

$$E = SG(\omega_2 - \omega_1)/\sqrt{2\pi(n-1)(A^{2/n} - 1)}. \quad (27)$$

It is interesting to note that the denominator of (27) approaches a limit as $n$ increases without limit. By ordinary methods it can be shown that

$$\lim_{n\to\infty} (n-1)(A^{2/n} - 1) = 2 \log (A) \quad (28)$$

then

$$E = SG(\omega_2 - \omega_1)/[2\sqrt{\pi \log (A)}]. \quad (29)$$

When, as is usual, $A$ is made equal to $\sqrt{2}$, (29) is

$$E = 0.48SG(\omega_2 - \omega_1). \quad (30)$$

The numerical factor of 0.48 in (30) applies when $n\to\infty$. For $n=5$ and $n=10$, as calculated by means of (27), this factor is 0.52 and 0.50, respectively. For values of $n>5$, the factor may be rounded off and made equal to 0.5. Equation (30) becomes finally

$$E = SG(\omega_2 - \omega_1)/2 \quad (31)$$

with a maximum probable error of less than 10 per cent when $5<n<Q/2$.

# A Calculator for Two-Element Directive Arrays*

J. G. ROUNTREE†, MEMBER, I.R.E.

*Summary*—**This article describes a mechanical device which may be used to calculate quickly the horizontal field pattern of a two-element directive array. The construction is not difficult and may readily be undertaken with only the usual drafting instruments, a protractor, and a set of mathematical tables.**

## Introduction

As THE number of standard broadcast stations has increased, more and more recourse has been made to the use of directive arrays to minimize interference to other stations operating on the same channel. The design and adjustment of these arrays has become a somewhat specialized field of consulting radio engineering, requiring as it does, a background of training and experience not usually found among the personnel of broadcast stations, and the use of instruments not always in possession of these stations.

This article describes a mechanical device which may be used to calculate quickly the horizontal field pattern of a two-element directive array.[1] While allocation problems in assignments of a number of recent stations have required that arrays of three or more elements be used, many existing directive arrays consist of only two elements. The calculation of the horizontal field pattern for a two-element array, although laborious, is not a too-difficult feat mathematically, and many patterns for these arrays are available for use as a starting point or as a guide.[2-4] However, it is felt that the calculator described herein can serve a useful purpose in determining the parameters for new directional installations and in determining the effects of changes in parameters of existing arrays, thereby enabling those who operate with such an array to observe the effect of a maladjustment of current or phasing on the horizontal pattern. The construction of this device is not difficult and may readily be undertaken with only the usual drafting instruments, a protractor, and a set of mathematical tables.

* Decimal classification: R325.1. Original manuscript received by the Institute, August 8, 1944.

† Federal Communications Commission, Dallas, Texas.

[1] Patent rights reserved.

[2] R. M. Foster, "Directive diagrams of antenna arrays," *Bell Sys. Tech. Jour.*, vol. 5, pp. 292–307; April, 1926.

[3] A. James Ebel, "Directional radiation patterns." *Electronics*, vol. 9, pp. 29–30; April, 1936.

[4] G. H. Brown, "Directional antennas," PROC. I.R.E., vol. 25, pp. 78–145; January, 1937.

## Principle of Operation

The principle upon which this device operates is that of vector solution. Fig. 1 indicates an array consisting

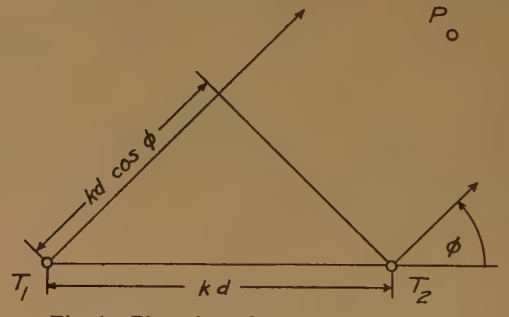



Fig. 1—Plan view of two-element array.

of two identical towers, spaced an electrical distance $kd$ degrees. At any point within the field of the antenna system, the field-strength component due to each element will be directly proportional to the current in that element, and the resultant field strength will be the resultant of the two voltage vectors at that point. Point $P$ is located sufficiently distant so that signals from the towers travel over substantially parallel paths. Assume that the current in $T_2$ leads the current in $T_1$ by $\angle a$ degrees. Then, since the signal from $T_1$ must travel the added distance $kd \cos \phi$, expressed as an angular portion of a wavelength, the voltage vector of $T_2$ at point $P$ will lead the voltage vector of $T_1$ by $a + kd \cos \phi$ degrees. (Fig. 2.) Regardless of the signs of $\angle a$ and of $kd \cos \phi$, the angle between the voltage vectors will be the algebraic sum. Positive values are used here merely for illustration.

As angle $\phi$ is varied from 0 to 360 degrees, that is, as point $P$ is shifted around the antenna system, vector $ET_2$ may be conceived of as describing an oscillation

about the end of vector $ET_1$. The center position of this oscillation, occurring at $\phi = 90$ degrees and at $\phi = 270$ degrees (i.e., $kd \cos \phi = 0$) is determined by the phasing of the towers, while the magnitude of oscillation is determined by the spacing of the towers.[5] (Fig. 3). With vector $ET_1$ as reference, the length of $ET_2$ is determined by the ratio of the field of $T_2$ to the field of $T_1$.[6] Where the towers are of differing heights, the length of vector $ET_2$ is also adjusted to account for the differing effective fields. In this calculator, the tower producing the larger vector is taken as the reference ($T_1$), and the vector is assigned the value of one ($ET_1 = 1$).

The calculator provides a mechanical means of evaluating $E_R$, the resultant vector, at any value of $\phi$ for differing values of phasing ($\angle a$), spacing ($kd$), and field ratios ($ET_2/ET_1$). The way in which this is done may be seen by a study of Fig. 3. A device consisting essentially of a fixed vector, corresponding to $ET_1$, and a rotary

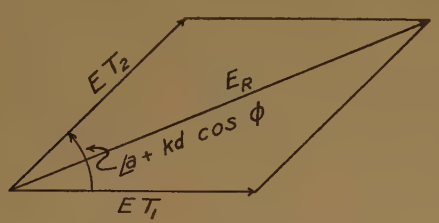



Fig. 2—Vector combination at point $P$.

vector, corresponding to $ET_2$, may be used to solve for $E_R$ if scales are provided to measure the following:

1. Ratio of $ET_2$ to $ET_1$
2. Center position of $ET_2$ (i.e., the phasing angle of the current in $T_2$ with respect to the current in $T_1$)
3. Rotation of $ET_2$ from the center position as $\phi$ varies, for various values of spacing ($kd$), and
4. Values of $E_R$.

These are provided in the calculator. Angle $\phi$ is measured from the $T_2$ end of the line of towers, and since the pattern of a two-element array is symmetrical about the line of towers, it is necessary only to measure values of $E_R$ for values of $\phi$ from 0 to 180 degrees.

## Scale Calibration

In appearance and construction, the device is similar to a circular slide rule and consists of a fixed base and a rotary circular element, both bearing scales, and a transparent rotary calibrated runner. (Fig. 4.) The fixed base, containing the $\phi$ scales and loci of points of the $kd$ scales, is laid out as follows:

A reference line is drawn upward from the pivot point of the rotary units. With the pivot point as a center, a series of circles and arcs is drawn whose radii correspond to various values of $kd$ ranging from 360 to 45 degrees. Other values could be included, but it is thought that this range is representative of most arrays. The innermost circle is the one to contain $\phi$ scales for $kd = 360$ degrees, and the intervals between succeeding circles and arcs correspond to decrements of 15 degrees in spacing, with two exceptions: Arcs are drawn for values of $kd = 138$ degrees and $kd = 316.5$ degrees. Spangenberg[7] has indicated that arrays with these spacings have cer-

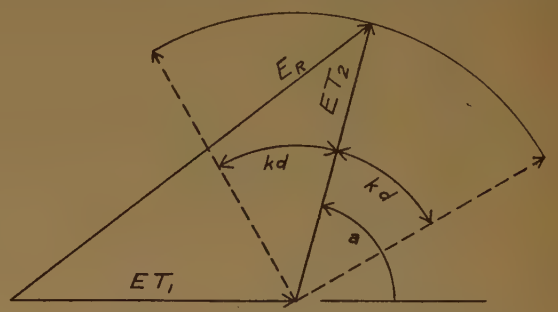



Fig. 3—Oscillation of vector $ET_2$ as angle $\phi$ is varied.

tain special characteristics, and scales are provided for these values for the purpose of allowing ready investigation of the patterns obtainable. The calibration marks on the runner allow values of spacing to be determined to 3 degrees.

The calibration mark for each value of $\phi$ on each arc or circle is determined as illustrated in Fig. 5. The arc contained between the calibration mark and the reference line subtends a central angle equal to $kd \cos \phi$. Thus the position of each calibration mark may be determined by measuring the central angle and projecting to the point of intersection on the circle or arc being scaled. Central angles for these scales are calculated by simple arithmetic, and results for the values selected are listed in Table I. Positive angles are measured counterclockwise from the reference line, and negative angles in a clockwise direction. Values for $\phi = 90$ degrees fall along the reference line, and isometric lines are drawn through all other values of $\phi$. These lines, when used in connection with the scale on the calibrated runner, allow the runner to be set to these values of $\phi$ for spacings intermediate of those represented by the circles and arcs.

On the perimeter of the rotary element is inscribed a protractor scale, calibrated from 0 to 180 degrees in both a negative direction (clockwise from 0 degrees) and a positive direction (counterclockwise from 0 degrees). This constitutes the phasing ($\angle a$) scale, which gives the phasing of $T_2$ with respect to $T_1$. In operation of this device, the phasing angle on this scale is set to the 90-degree line of the $\phi$ scales (the reference line), for at $\phi = 90$ degrees, the angle between the vectors is equal to the phasing angle.

Located on this rotary element are resultant vector scales, in circular form, from which the value of $E_R$ is

[5] F. Alton Everest and Wilson S. Pritchett, "Horizontal-polar-pattern tracer for directional broadcast antennas," Proc. I.R.E., vol. 30, pp. 227–232; May, 1942.

[6] John F. Morrison, "Simple method for observing current amplitude and phase relations in antenna arrays," Proc. I.R.E., vol. 25, pp. 1310–1326; October, 1937.

[7] Karl Spangenberg, "Charts for the determination of the root-mean-square value of the horizontal radiation pattern of two-element broadcast antenna arrays," Proc. I.R.E., vol. 30, pp. 237–240; May, 1942.

obtained, for ratios of $ET_2/ET_1$ ranging from 0.2 to 1.0 in steps of 0.1. Isometric lines are drawn through equal points on the $E_R$ scales, so that by means of the calibrated runner, values of $ET_2/ET_1$ determined to 0.02 may be used.

This equation is placed in form (3) so that the results obtained may be most useful in plotting points along the $E_R$ scales, for in this form, the values of $a+kd\cos\phi$ may be determined for desired decimal values of $E_R$. Where $ET_2/ET_1=1$, $(ET_2=ET_1=1)$, equation (3) becomes

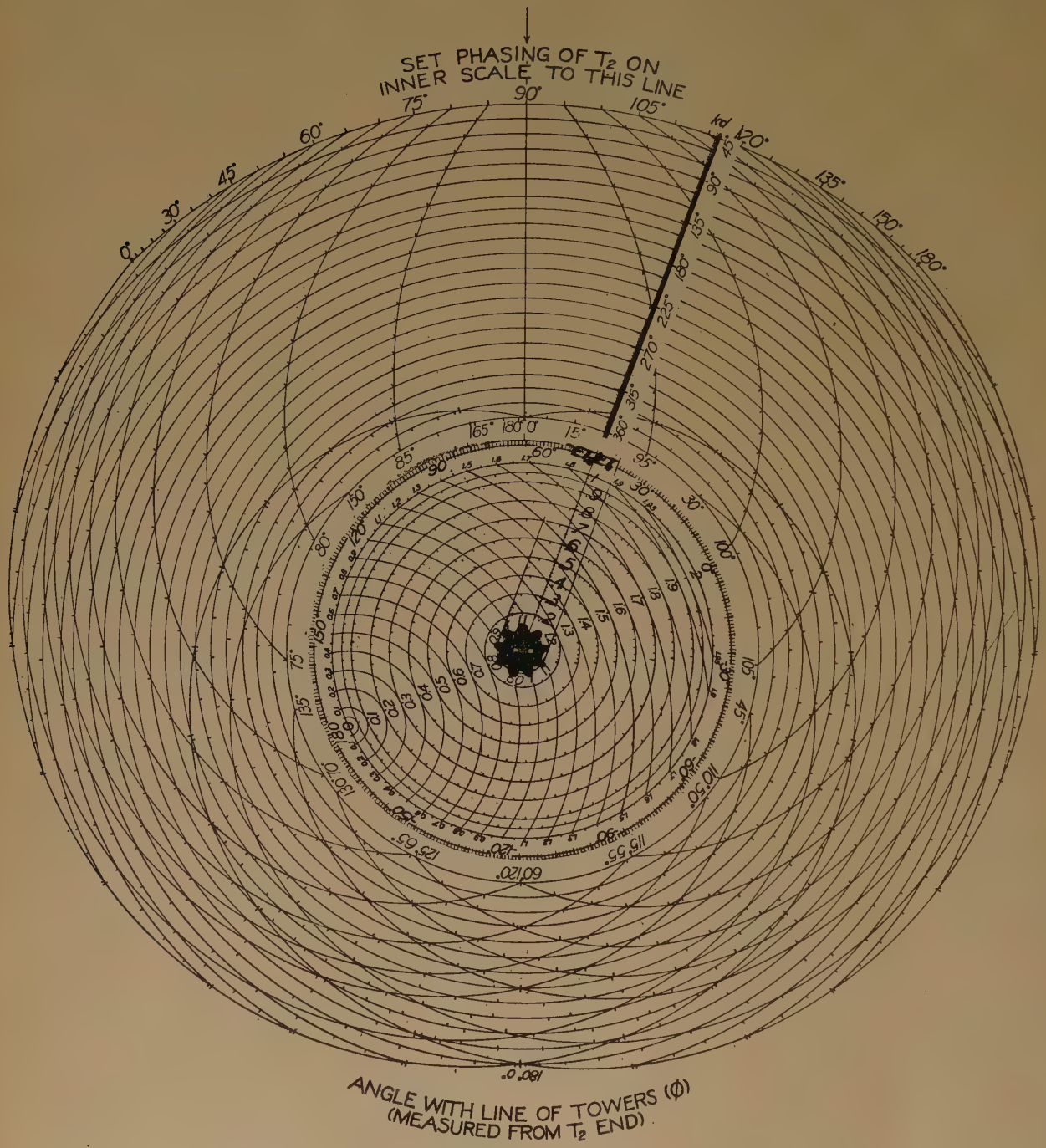



Fig. 4—The horizontal-pattern calculator for two-element directive arrays.

The $E_R$ scales are computed trigonometrically, as illustrated in Fig. 6. Here, by the law of cosines:

$$E_R^2 = ET_1^2 + ET_2^2 - 2ET_1ET_2\cos(180 \text{ degrees} - \overline{a + kd\cos\phi}) \quad (1)$$

$$E_R^2 = ET_1^2 + ET_2^2 + 2ET_1ET_2\cos(a + kd\cos\phi) \quad (2)$$

$$\cos(a + kd\cos\phi) = (E_R^2 - ET_1^2 - ET_2^2)/(2ET_1ET_2). \quad (3)$$

$$\cos(\overline{a + kd\cos\phi}/2) = E_R/2. \quad (4)$$

The results obtained for the values selected are listed in Tables II to XI. As in the case of the fixed base, each calibration mark is determined by measuring the central angle and projecting to the point of intersection on the circle being scaled. (Fig. 7.) This angle may be measured directly on the protractor scale along the edge of the

TABLE I

CENTRAL ANGLES FOR CALIBRATION OF $\phi$ SCALES

| $\phi$ | $kd \cos \phi$ | | | | | |
|---|---|---|---|---|---|---|
| | $kd=45$ degrees | $kd=60$ degrees | $kd=75$ degrees | $kd=90$ degrees | $kd=105$ degrees | $kd=120$ degrees |
| Degrees | Degrees | Degrees | Degrees | Degrees | Degrees | Degrees |
| 0 | 45.0000 | 60.0000 | 75.0000 | 90.0000 | 105.0000 | 120.0000 |
| 5 | 44.8286 | 59.7714 | 74.7143 | 89.6571 | 104.6000 | 119.5428 |
| 10 | 44.3165 | 59.0886 | 73.8608 | 88.6329 | 103.4051 | 118.1772 |
| 15 | 43.4669 | 57.9558 | 72.4448 | 86.9337 | 101.4227 | 115.9116 |
| 20 | 42.2861 | 56.3814 | 70.4768 | 84.5721 | 98.6675 | 112.7628 |
| 25 | 40.7840 | 54.3786 | 67.9533 | 81.5679 | 95.1626 | 108.7572 |
| 30 | 38.9714 | 51.9618 | 64.9523 | 77.9427 | 90.9332 | 103.9236 |
| 35 | 36.8618 | 49.1490 | 61.4363 | 73.7235 | 86.1108 | 98.2980 |
| 40 | 34.4718 | 45.9624 | 57.4530 | 68.9436 | 80.4342 | 91.9248 |
| 45 | 31.8200 | 42.4266 | 53.0333 | 63.6399 | 74.2466 | 84.8532 |
| 50 | 28.9256 | 38.5674 | 48.2093 | 57.8511 | 67.4930 | 77.1348 |
| 55 | 25.8110 | 34.4148 | 43.0185 | 51.6220 | 60.2259 | 68.8296 |
| 60 | 22.5000 | 30.0000 | 37.5000 | 45.0000 | 52.5000 | 60.0000 |
| 65 | 19.0179 | 25.3572 | 31.6965 | 38.0358 | 44.3751 | 50.7144 |
| 70 | 15.3909 | 20.5212 | 25.6515 | 30.7818 | 35.9121 | 41.0424 |
| 75 | 11.6469 | 15.5292 | 19.4115 | 23.2938 | 27.1761 | 31.0548 |
| 80 | 7.8143 | 10.4190 | 13.0238 | 15.6285 | 18.2333 | 20.8380 |
| 85 | 3.9222 | 5.2296 | 6.5370 | 7.8444 | 9.1518 | 10.4592 |
| 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 95 | − 3.9222 | − 5.2296 | − 6.5370 | − 7.8444 | − 9.1518 | − 10.4592 |
| 100 | − 7.8143 | − 10.4190 | − 13.0238 | − 15.6285 | − 18.2333 | − 20.8380 |
| 105 | − 11.6469 | − 15.5292 | − 19.4115 | − 23.2938 | − 27.1761 | − 31.0584 |
| 110 | − 15.3909 | − 20.5212 | − 25.6515 | − 30.7818 | − 35.9121 | − 41.0424 |
| 115 | − 19.0179 | − 25.3572 | − 31.6965 | − 38.0358 | − 44.3751 | − 50.7144 |
| 120 | − 22.5000 | − 30.0000 | − 37.5000 | − 45.0000 | − 52.5000 | − 60.0000 |
| 125 | − 25.8110 | − 34.4148 | − 43.0185 | − 51.6220 | − 60.2259 | − 68.8296 |
| 130 | − 28.9256 | − 38.5674 | − 48.2093 | − 57.8511 | − 67.4930 | − 77.1348 |
| 135 | − 31.8200 | − 42.4266 | − 53.0333 | − 63.6399 | − 74.2466 | − 84.8532 |
| 140 | − 34.4718 | − 45.9624 | − 57.4530 | − 68.9436 | − 80.4342 | − 91.9248 |
| 145 | − 36.8618 | − 49.1490 | − 61.4363 | − 73.7235 | − 86.1108 | − 98.2980 |
| 150 | − 38.9714 | − 51.9618 | − 64.9523 | − 77.9427 | − 90.9332 | −103.9236 |
| 155 | − 40.7840 | − 54.3786 | − 67.9533 | − 81.5679 | − 95.1626 | −108.7572 |
| 160 | − 42.2861 | − 56.3814 | − 70.4768 | − 84.5721 | − 98.6675 | −112.7628 |
| 165 | − 43.4669 | − 57.9558 | − 72.4448 | − 86.9337 | −101.4227 | −115.9116 |
| 170 | − 44.3165 | − 59.0886 | − 73.8608 | − 88.6329 | −103.4051 | −118.1772 |
| 175 | − 44.8286 | − 59.7714 | − 74.7143 | − 89.6571 | −104.6000 | −119.5428 |
| 180 | − 45.0000 | − 60.0000 | − 75.0000 | − 90.0000 | −105.0000 | −120.0000 |

| $\phi$ | $kd \cos \phi$ | | | | | |
|---|---|---|---|---|---|---|
| | $kd=225$ degrees | $kd=240$ degrees | $kd=255$ degrees | $kd=270$ degrees | $kd=285$ degrees | |
| Degrees | Degrees | Degrees | Degrees | Degrees | Degrees | |
| 0 | 225.0000 | 240.0000 | 255.0000 | 270.0000 | 285.0000 | |
| 5 | 224.1428 | 239.0856 | 254.0285 | 268.9713 | 283.9142 | |
| 10 | 221.5823 | 236.3544 | 251.1266 | 265.8987 | 280.6709 | |
| 15 | 217.3343 | 231.8232 | 246.3122 | 260.7011 | 275.2901 | |
| 20 | 211.4303 | 225.5256 | 239.6210 | 253.7163 | 267.8117 | |
| 25 | 203.9198 | 217.5144 | 231.1091 | 244.7037 | 258.2982 | |
| 30 | 194.8568 | 207.8472 | 220.8377 | 233.8281 | 246.8186 | |
| 35 | 184.3088 | 196.5960 | 208.8833 | 221.1705 | 233.4578 | |
| 40 | 172.3590 | 183.8496 | 195.3402 | 206.8308 | 218.3214 | |
| 45 | 159.0998 | 169.7064 | 180.3131 | 190.9197 | 201.5264 | |
| 50 | 144.6278 | 154.2696 | 163.9115 | 173.5533 | 183.1952 | |
| 55 | 129.0555 | 137.6592 | 146.2629 | 154.8666 | 163.4703 | |
| 60 | 112.5000 | 120.0000 | 127.5000 | 135.0000 | 142.5000 | |
| 65 | 95.0895 | 101.4288 | 107.7681 | 114.1074 | 120.4467 | |
| 70 | 76.9545 | 82.0848 | 87.2151 | 92.3454 | 97.4757 | |
| 75 | 58.2345 | 62.1168 | 65.9991 | 69.8814 | 73.7637 | |
| 80 | 39.0713 | 41.6760 | 44.2808 | 46.8855 | 49.4903 | |
| 85 | 19.6110 | 20.9184 | 22.2258 | 23.5332 | 24.8406 | |
| 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 95 | − 19.6110 | − 20.9184 | − 22.2258 | − 23.5332 | − 24.8406 | |
| 100 | − 39.0713 | − 41.6760 | − 44.2808 | − 46.8855 | − 49.4903 | |
| 105 | − 58.2345 | − 62.1168 | − 65.9991 | − 69.8814 | − 73.7637 | |
| 110 | − 76.9545 | − 82.0848 | − 87.2151 | − 92.3454 | − 97.4757 | |
| 115 | − 95.0895 | −101.4288 | −107.7681 | −114.1074 | −120.4467 | |
| 120 | −112.5000 | −120.0000 | −127.5000 | −135.0000 | −142.5000 | |
| 125 | −129.0555 | −137.6592 | −146.2629 | −154.8666 | −163.4703 | |
| 130 | −144.6278 | −154.2696 | −163.9115 | −173.5533 | −183.1952 | |
| 135 | −159.0998 | −169.7064 | −180.3131 | −190.9197 | −201.5264 | |
| 140 | −172.3590 | −183.8496 | −195.3402 | −206.8308 | −218.3214 | |
| 145 | −184.3088 | −196.5960 | −208.8833 | −221.1705 | −233.4578 | |
| 150 | −194.8568 | −207.8472 | −220.8377 | −233.8281 | −246.8186 | |
| 155 | −203.9198 | −217.5144 | −231.1091 | −244.7037 | −258.2982 | |
| 160 | −211.4303 | −225.5256 | −239.6210 | −253.7163 | −267.8117 | |
| 165 | −217.3343 | −231.8232 | −246.3122 | −260.7011 | −275.2901 | |
| 170 | −221.5823 | −236.3544 | −251.1266 | −265.8987 | −280.6709 | |
| 175 | −224.1428 | −239.0856 | −254.0285 | −268.9713 | −283.9142 | |
| 180 | −225.0000 | −240.0000 | −255.0000 | −270.0000 | −285.0000 | |

| $\phi$ | $kd \cos \phi$ | | | | | |
|---|---|---|---|---|---|---|
| | $kd=138$ degrees | $kd=150$ degrees | $kd=165$ degrees | $kd=180$ degrees | $kd=195$ degrees | $kd=210$ degrees |
| Degrees | Degrees | Degrees | Degrees | Degrees | Degrees | Degrees |
| 0 | 138.0000 | 150.0000 | 165.0000 | 180.0000 | 195.0000 | 210.0000 |
| 5 | 137.4742 | 149.4285 | 164.3714 | 179.3142 | 194.2571 | 209.1999 |
| 10 | 135.9038 | 147.7215 | 162.4937 | 177.2658 | 192.0380 | 206.8101 |
| 15 | 133.2983 | 144.8895 | 159.3785 | 173.8674 | 188.3564 | 202.8453 |
| 20 | 129.6772 | 140.9535 | 155.0489 | 169.1442 | 183.2396 | 197.3349 |
| 25 | 125.0708 | 135.9465 | 149.5412 | 163.1358 | 176.7305 | 190.3251 |
| 30 | 119.5121 | 129.9045 | 142.8949 | 155.8854 | 168.8759 | 181.8663 |
| 35 | 113.0427 | 122.8725 | 135.1598 | 147.4470 | 159.7343 | 172.0215 |
| 40 | 105.7135 | 114.9060 | 126.3966 | 137.8872 | 149.3778 | 160.8684 |
| 45 | 97.5812 | 106.0665 | 116.6707 | 127.2798 | 137.8865 | 148.4931 |
| 50 | 88.7050 | 96.4185 | 106.0604 | 115.7022 | 125.3441 | 134.9859 |
| 55 | 79.1540 | 86.0370 | 94.6407 | 103.2444 | 111.8481 | 120.4518 |
| 60 | 69.0000 | 75.0000 | 82.5000 | 90.0000 | 97.5000 | 105.0000 |
| 65 | 58.3216 | 63.3930 | 69.7323 | 76.0716 | 82.4109 | 88.7502 |
| 70 | 47.1988 | 51.3030 | 56.4333 | 61.5636 | 66.6939 | 71.8242 |
| 75 | 35.7172 | 38.8230 | 42.7053 | 46.5876 | 50.4699 | 54.3522 |
| 80 | 23.9637 | 26.0475 | 28.6523 | 31.2570 | 33.8618 | 36.4665 |
| 85 | 12.0281 | 13.0740 | 14.3814 | 15.6888 | 16.9962 | 18.3036 |
| 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 95 | − 12.0281 | − 13.0740 | − 14.3814 | − 15.6888 | − 16.9962 | − 18.3036 |
| 100 | − 23.9637 | − 26.0475 | − 28.6523 | − 31.2570 | − 33.8618 | − 36.4665 |
| 105 | − 35.7172 | − 38.8230 | − 42.7053 | − 46.5876 | − 50.4699 | − 54.3522 |
| 110 | − 47.1988 | − 51.3030 | − 56.4333 | − 61.5636 | − 66.6939 | − 71.8242 |
| 115 | − 58.3216 | − 63.3930 | − 69.7323 | − 76.0716 | − 82.4109 | − 88.7502 |
| 120 | − 69.0000 | − 75.0000 | − 82.5000 | − 90.0000 | − 97.5000 | −105.0000 |
| 125 | − 79.1540 | − 86.0370 | − 94.6407 | −103.2444 | −111.8481 | −120.4518 |
| 130 | − 88.7050 | − 96.4185 | −106.0604 | −115.7022 | −125.3441 | −134.9859 |
| 135 | − 97.5812 | −106.0665 | −116.6707 | −127.2798 | −137.8865 | −148.4931 |
| 140 | −105.7135 | −114.9060 | −126.3966 | −137.8872 | −149.3778 | −160.8684 |
| 145 | −113.0427 | −122.8725 | −135.1598 | −147.4470 | −159.7343 | −172.0215 |
| 150 | −119.5121 | −129.9045 | −142.8949 | −155.8854 | −168.8759 | −181.8663 |
| 155 | −125.0708 | −135.9465 | −149.5412 | −163.1358 | −176.7305 | −190.3251 |
| 160 | −129.6772 | −140.9535 | −155.0489 | −169.1442 | −183.2396 | −197.3349 |
| 165 | −133.2983 | −144.8895 | −159.3785 | −173.8674 | −188.3564 | −202.8453 |
| 170 | −135.9038 | −147.7215 | −162.4937 | −177.2658 | −192.0380 | −206.8101 |
| 175 | −137.4742 | −149.4285 | −164.3714 | −179.3142 | −194.2571 | −209.1999 |
| 180 | −138.0000 | −150.0000 | −165.0000 | −180.0000 | −195.0000 | −210.0000 |

| $\phi$ | $kd \cos \phi$ | | | | | |
|---|---|---|---|---|---|---|
| | $kd=300$ degrees | $kd=316.5$ degrees | $kd=330$ degrees | $kd=345$ degrees | $kd=360$ degrees | |
| Degrees | Degrees | Degrees | Degrees | Degrees | Degrees | |
| 0 | 300.0000 | 316.5000 | 330.0000 | 345.0000 | 360.0000 | |
| 5 | 298.8570 | 315.2941 | 328.7427 | 343.6856 | 358.6284 | |
| 10 | 295.4430 | 311.6924 | 324.9873 | 339.7595 | 354.5316 | |
| 15 | 289.7790 | 305.7168 | 318.7569 | 333.2459 | 347.7348 | |
| 20 | 281.9070 | 297.4119 | 310.0977 | 324.1931 | 338.3884 | |
| 25 | 271.8930 | 286.8471 | 299.0823 | 312.6770 | 326.2716 | |
| 30 | 259.8090 | 274.0985 | 285.7899 | 298.7804 | 311.7708 | |
| 35 | 245.7450 | 259.2610 | 270.3195 | 282.6068 | 294.8940 | |
| 40 | 229.8120 | 242.4517 | 252.7932 | 264.2838 | 275.7744 | |
| 45 | 212.1330 | 223.8003 | 233.3463 | 243.9530 | 254.5596 | |
| 50 | 192.8370 | 203.4430 | 212.1207 | 221.7626 | 231.4044 | |
| 55 | 172.0740 | 181.5381 | 189.2814 | 197.8851 | 206.4888 | |
| 60 | 150.0000 | 158.2500 | 165.0000 | 172.5000 | 180.0000 | |
| 65 | 126.7860 | 133.7592 | 139.4646 | 145.8039 | 152.1432 | |
| 70 | 102.6060 | 108.2493 | 112.8666 | 117.9969 | 123.1272 | |
| 75 | 77.6460 | 81.9165 | 85.4106 | 89.2929 | 93.1752 | |
| 80 | 52.0950 | 54.9602 | 57.3045 | 59.9093 | 62.5140 | |
| 85 | 26.1480 | 27.5861 | 28.7628 | 30.0702 | 31.3776 | |
| 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| 95 | − 26.1480 | − 27.5861 | − 28.7628 | − 30.0702 | − 31.3776 | |
| 100 | − 52.0950 | − 54.9602 | − 57.3045 | − 59.9093 | − 62.5140 | |
| 105 | − 77.6460 | − 81.9165 | − 85.4106 | − 89.2929 | − 93.1752 | |
| 110 | −102.6060 | −108.2493 | −112.8666 | −117.9969 | −123.1272 | |
| 115 | −126.7860 | −133.7592 | −139.4646 | −145.8039 | −152.1432 | |
| 120 | −150.0000 | −158.2500 | −165.0000 | −172.5000 | −180.0000 | |
| 125 | −172.0740 | −181.5381 | −189.2814 | −197.8851 | −206.4888 | |
| 130 | −192.8370 | −203.4430 | −212.1207 | −221.7626 | −231.4044 | |
| 135 | −212.1330 | −223.8003 | −233.3463 | −243.9530 | −254.5596 | |
| 140 | −229.8120 | −242.4517 | −252.7932 | −264.2838 | −275.7744 | |
| 145 | −245.7450 | −259.2610 | −270.3195 | −282.6068 | −294.8940 | |
| 150 | −259.8090 | −274.0985 | −285.7899 | −298.7804 | −311.7708 | |
| 155 | −271.8930 | −286.8471 | −299.0823 | −312.6770 | −326.2716 | |
| 160 | −281.9070 | −297.4119 | −310.0977 | −324.1931 | −338.3884 | |
| 165 | −289.7790 | −305.7168 | −318.7569 | −333.2459 | −347.7348 | |
| 170 | −295.4430 | −311.6924 | −324.9873 | −339.7595 | −354.5316 | |
| 175 | −298.8570 | −315.2941 | −328.7427 | −343.6856 | −358.6284 | |
| 180 | −300.0000 | −316.5000 | −330.0000 | −345.0000 | −360.0000 | |

element ($\angle a$ scale). For this purpose, the term $kd \cos \phi$ and the sign of $\angle a$ have no significance and may be ignored.

This construction may be simplified if the circular resultant vector scales are drawn so that the inner scale, representing $ET_2/ET_1=0.2$, has a radius two units in length, and the succeeding scales, representing increments of 0.1, are drawn with radii successively one unit longer. Then the isometric lines representing equal values of $E_R$ may be drawn as arcs having the point $E_R=0$ as their center and having radii equal to the value of $E_R$, measured in the same units as $ET_2/ET_1$. The rotary element of Fig. 4 illustrates this construction.

The rotary runner, in the section covering the $\phi$ scales, is calibrated in steps of 3 degrees for values of $kd$ between 45 and 360 degrees, and in the section covering the vector scales, it is calibrated in steps of 0.02 for values of $E_2/ET_1$ between 0.2 and 1.0. Referring to Figs. 3 and 4, vector $ET_1$ may be visualized as being located on the rotary element, with its origin at the

value $E_R=0$ and its head at the pivot point of the element. Likewise, vector $ET_2$ may be visualized as having its origin at the pivot point of the rotary runner and as

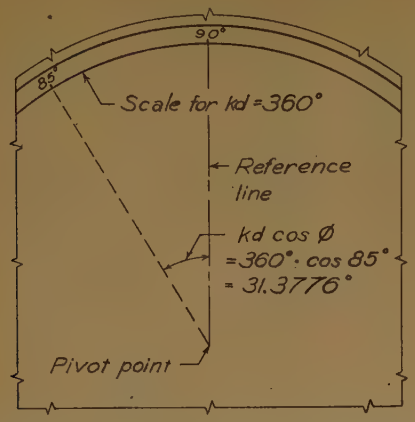



Fig. 5—Method of calibrating $\phi$ scales. Illustrated is the determination of the calibration point for $\phi=85$ degrees on the scale for $kd=360$ degrees.

lying along the calibrated scale of the runner, with its head at a point determined by its relative magnitude.

In the construction of a calculator for an existing array, it is necessary to plot only one $\phi$ scale. If a change in frequency were contemplated, and it were desired that the existing tower arrangement be used, a new $\phi$ scale would have to be plotted for the changed value of electrical spacing ($kd$). Likewise, only that range of $ET_2/ET_1$ of interest to the station concerned need be plotted.

## Operation

In operating this device to determine the horizontal field pattern of an array having known parameters, the

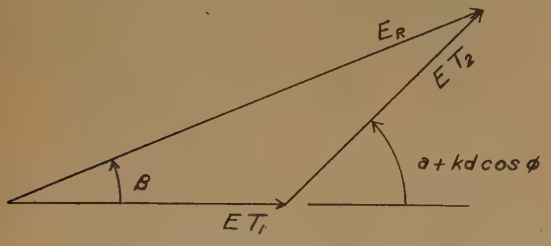



Fig. 6—Trigonometry of resultant vector-scale calculation.

towers are designated $T_1$ and $T_2$, with $T_1$ designating the tower producing the larger field-strength component, if they are unequal. The line of towers, $T_1-T_2$, is marked on polar graph paper, and angles of $\phi$ are measured from the $T_2$ end of this line. The phasing of $T_2$ on the $\angle\alpha$ scale is set to the reference line, and the calibrated runner is moved to successive values of $\phi$ for the particular electrical spacing involved. At each value of $\phi$, the value of $E_R$ will be found on the vector scales under the calibration point on the runner corresponding to the ratio of $ET_2/ET_1$ being used. Plotting these values on the polar graph paper will give the horizontal pattern of the array.

In the determination of parameters for an array to fit a particular allocation problem, a value of $kd$ may be selected and the runner set to the value of $\phi$ representing the direction in which the minimum signal is to be radiated. Move the rotary element to the point where $E_R=0$ is under the marker on the runner. Then the

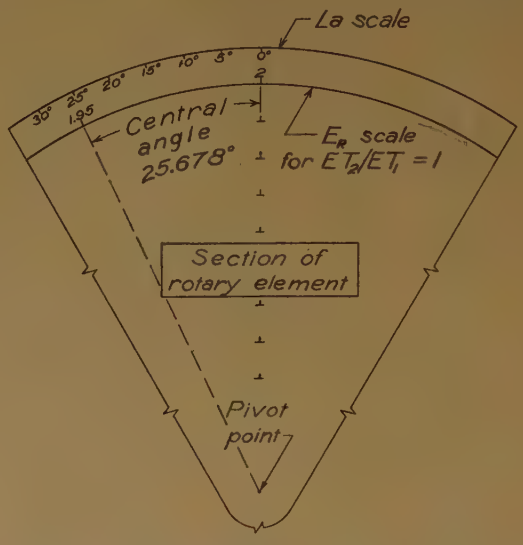



Fig. 7—Method of calibrating $E_R$ scales. Illustrated is the determination of the calibration point for $E_R=1.95$ on the scale for $ET_2/ET_1=1$. The calibration mark designates the end of the arc which subtends the central angle determined from Table II. This angle may be measured on the $\angle\alpha$ scale.

TABLE II

Central Angles for Calibration of $E_R$ Scale When $ET_2/ET_1=1.00$

| $E_R$ | $\alpha+kd\cos\phi$ | $E_R$ | $\alpha+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 2.00 | 0.000 | 1.05 | 116.668 |
| 1.99 | 11.466 | 1.00 | 120.000 |
| 1.98 | 16.265 | 0.95 | 123.281 |
| 1.97 | 19.872 | 0.90 | 126.512 |
| 1.96 | 22.955 | 0.85 | 129.699 |
| 1.95 | 25.678 | 0.80 | 132.843 |
| 1.90 | 36.388 | 0.75 | 135.952 |
| 1.85 | 44.667 | 0.70 | 139.024 |
| 1.80 | 51.683 | 0.65 | 142.069 |
| 1.75 | 57.908 | 0.60 | 145.083 |
| 1.70 | 63.578 | 0.55 | 148.077 |
| 1.65 | 68.823 | 0.50 | 151.044 |
| 1.60 | 73.738 | 0.45 | 153.995 |
| 1.55 | 78.388 | 0.40 | 156.925 |
| 1.50 | 82.819 | 0.35 | 159.842 |
| 1.45 | 87.062 | 0.30 | 162.747 |
| 1.40 | 91.147 | 0.25 | 165.638 |
| 1.35 | 95.093 | 0.20 | 168.521 |
| 1.30 | 98.916 | 0.15 | 171.340 |
| 1.25 | 102.635 | 0.10 | 174.266 |
| 1.20 | 106.261 | 0.05 | 177.145 |
| 1.15 | 109.801 | 0.00 | 180.000 |
| 1.10 | 113.266 | | |

TABLE III

Central Angles for Calibration of $E_R$ Scale When $ET_2/ET_1=0.95$ (5 Per Cent Unbalance of $ET_2/ET_1=1$)

| $E_R$ | $\alpha+kd\cos\phi$ | $E_R$ | $\alpha+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.95 | 0.000 | 1.05 | 114.906 |
| 1.94 | 11.616 | 1.00 | 118.359 |
| 1.93 | 16.156 | 0.95 | 121.755 |
| 1.92 | 20.133 | 0.90 | 125.099 |
| 1.91 | 23.258 | 0.85 | 128.392 |
| 1.90 | 26.015 | 0.80 | 131.641 |
| 1.85 | 36.870 | 0.75 | 134.851 |
| 1.80 | 45.255 | 0.70 | 138.085 |
| 1.75 | 52.373 | 0.65 | 141.164 |
| 1.70 | 58.686 | 0.60 | 144.276 |
| 1.65 | 64.432 | 0.55 | 147.418 |
| 1.60 | 69.752 | 0.50 | 150.428 |
| 1.55 | 74.743 | 0.45 | 153.492 |
| 1.50 | 79.456 | 0.40 | 156.506 |
| 1.45 | 83.957 | 0.35 | 159.527 |
| 1.40 | 88.266 | 0.30 | 162.539 |
| 1.35 | 92.412 | 0.25 | 165.562 |
| 1.30 | 96.443 | 0.20 | 168.598 |
| 1.25 | 100.308 | 0.15 | 171.680 |
| 1.20 | 104.089 | 0.10 | 174.905 |
| 1.15 | 107.774 | 0.05 | 180.000 |
| 1.10 | 111.375 | | |

TABLE IV

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALE WHEN $ET_3/ET_1=0.9$

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.90 | 0.000 | 1.05 | 113.144 |
| 1.89 | 11.780 | 1.00 | 116.745 |
| 1.88 | 16.665 | 0.95 | 120.276 |
| 1.87 | 20.419 | 0.90 | 123.749 |
| 1.86 | 23.589 | 0.85 | 127.169 |
| 1.85 | 26.389 | 0.80 | 130.542 |
| 1.80 | 37.398 | 0.75 | 133.872 |
| 1.75 | 45.906 | 0.70 | 137.167 |
| 1.70 | 53.130 | 0.65 | 140.429 |
| 1.65 | 59.540 | 0.60 | 143.669 |
| 1.60 | 65.376 | 0.55 | 146.877 |
| 1.55 | 70.782 | 0.50 | 150.073 |
| 1.50 | 75.863 | 0.45 | 153.260 |
| 1.45 | 80.647 | 0.40 | 156.444 |
| 1.40 | 85.220 | 0.35 | 159.634 |
| 1.35 | 89.603 | 0.30 | 162.854 |
| 1.30 | 93.822 | 0.25 | 166.126 |
| 1.25 | 97.903 | 0.20 | 169.523 |
| 1.20 | 101.862 | 0.15 | 173.242 |
| 1.15 | 105.714 | 0.10 | 180.000 |
| 1.10 | 109.471 | | |

TABLE V

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALE WHEN $ET_3/ET_1=0.8$

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.80 | 0.000 | 1.05 | 109.487 |
| 1.79 | 12.167 | 1.00 | 113.584 |
| 1.78 | 17.200 | 0.95 | 117.450 |
| 1.77 | 21.083 | 0.90 | 121.200 |
| 1.76 | 24.355 | 0.85 | 124.990 |
| 1.75 | 27.250 | 0.80 | 128.683 |
| 1.70 | 38.550 | 0.75 | 132.300 |
| 1.65 | 47.383 | 0.70 | 135.952 |
| 1.60 | 54.933 | 0.65 | 139.550 |
| 1.55 | 61.566 | 0.60 | 143.133 |
| 1.50 | 67.600 | 0.55 | 146.667 |
| 1.45 | 73.200 | 0.50 | 150.233 |
| 1.40 | 78.466 | 0.45 | 153.833 |
| 1.35 | 83.450 | 0.40 | 157.667 |
| 1.30 | 88.150 | 0.35 | 161.458 |
| 1.25 | 92.775 | 0.30 | 165.466 |
| 1.20 | 97.183 | 0.25 | 170.584 |
| 1.15 | 101.433 | 0.20 | 180.000 |
| 1.10 | 105.575 | | |

TABLE VI

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALE WHEN $ET_3/ET_1=0.7$

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.70 | 0.000 | 1.05 | 106.068 |
| 1.69 | 12.634 | 1.00 | 110.487 |
| 1.68 | 17.871 | 0.95 | 114.814 |
| 1.67 | 21.910 | 0.90 | 119.059 |
| 1.66 | 25.311 | 0.85 | 123.244 |
| 1.65 | 28.316 | 0.80 | 127.384 |
| 1.60 | 40.157 | 0.75 | 131.491 |
| 1.55 | 49.324 | 0.70 | 135.585 |
| 1.50 | 57.120 | 0.65 | 139.685 |
| 1.45 | 64.056 | 0.60 | 143.818 |
| 1.40 | 70.384 | 0.55 | 148.018 |
| 1.35 | 76.261 | 0.50 | 152.336 |
| 1.30 | 81.787 | 0.45 | 156.873 |
| 1.25 | 87.032 | 0.40 | 161.805 |
| 1.20 | 92.047 | 0.35 | 167.630 |
| 1.15 | 96.872 | 0.30 | 180.000 |
| 1.10 | 101.537 | | |

TABLE VII

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALE WHEN $ET_3/ET_1=0.6$

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.60 | 0.000 | 1.00 | 107.458 |
| 1.59 | 13.242 | 0.95 | 112.411 |
| 1.58 | 18.736 | 0.90 | 117.279 |
| 1.57 | 22.964 | 0.85 | 122.090 |
| 1.56 | 26.533 | 0.80 | 126.870 |
| 1.55 | 29.686 | 0.75 | 131.650 |
| 1.50 | 42.126 | 0.70 | 136.497 |
| 1.45 | 51.760 | 0.65 | 141.392 |
| 1.40 | 60.000 | 0.60 | 146.443 |
| 1.35 | 67.330 | 0.55 | 151.793 |
| 1.30 | 74.038 | 0.50 | 157.667 |
| 1.25 | 80.285 | 0.45 | 164.705 |
| 1.20 | 86.177 | 0.40 | 180.000 |
| 1.15 | 91.790 | | |
| 1.10 | 97.181 | | |
| 1.05 | 102.391 | | |

TABLE VIII

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALES WHEN $ET_3/ET_1=0.5$ AND 0.4, RESPECTIVELY

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.50 | 0.000 | 1.40 | 0.000 |
| 1.49 | 14.045 | 1.39 | 15.176 |
| 1.48 | 19.882 | 1.38 | 21.487 |
| 1.47 | 24.369 | 1.37 | 26.342 |
| 1.46 | 28.164 | 1.36 | 30.458 |
| 1.45 | 31.483 | 1.35 | 34.110 |
| 1.40 | 44.766 | 1.30 | 48.508 |
| 1.35 | 55.075 | 1.25 | 59.783 |
| 1.30 | 63.900 | 1.20 | 69.512 |
| 1.25 | 71.790 | 1.15 | 78.283 |
| 1.20 | 79.050 | 1.10 | 86.417 |
| 1.15 | 85.843 | 1.05 | 94.121 |
| 1.10 | 92.293 | 1.00 | 101.537 |
| 1.05 | 98.483 | 0.95 | 108.772 |
| 1.00 | 104.478 | 0.90 | 115.944 |
| 0.95 | 110.333 | 0.85 | 123.150 |
| 0.90 | 116.100 | 0.80 | 130.542 |
| 0.85 | 121.833 | 0.75 | 138.317 |
| 0.80 | 127.587 | 0.70 | 146.883 |
| 0.75 | 133.434 | 0.65 | 157.203 |
| 0.70 | 139.466 | 0.60 | 180.000 |
| 0.65 | 145.850 | | |
| 0.60 | 152.873 | | |
| 0.55 | 161.350 | | |
| 0.50 | 180.000 | | |

TABLE X TABLE XI

CENTRAL ANGLES FOR CALIBRATION OF $E_R$ SCALES WHEN $ET_3/ET_1=0.3$ AND 0.2, RESPECTIVELY

| $E_R$ | $a+kd\cos\phi$ | $E_R$ | $a+kd\cos\phi$ |
|---|---|---|---|
| | Degrees | | Degrees |
| 1.30 | 0.000 | 1.20 | 0.000 |
| 1.29 | 16.896 | 1.19 | 19.906 |
| 1.28 | 23.936 | 1.18 | 28.237 |
| 1.27 | 29.366 | 1.17 | 34.689 |
| 1.26 | 33.970 | 1.16 | 40.182 |
| 1.25 | 38.047 | 1.15 | 45.069 |
| 1.20 | 54.314 | 1.10 | 64.849 |
| 1.15 | 67.201 | 1.05 | 81.011 |
| 1.10 | 78.463 | 1.00 | 95.740 |
| 1.05 | 88.806 | 0.95 | 110.105 |
| 1.00 | 98.627 | 0.90 | 125.099 |
| 0.95 | 108.210 | 0.85 | 142.520 |
| 0.90 | 117.819 | 0.80 | 180.000 |
| 0.85 | 127.770 | | |
| 0.80 | 138.590 | | |
| 0.75 | 151.543 | | |
| 0.70 | 180.000 | | |

desired phasing of $T_2$ may be read from the $\angle a$ scale at the reference line. Repeating the process for other values of $kd$ will enable one to obtain a group of patterns, with the parameters in each case, all producing a minimum signal in the desired direction in the horizontal plane. From these, the pattern to be used may be selected. Other procedures will suggest themselves to the experienced engineer.

It is, of course, important that the field radiated in the vertical plane also be considered in any allocation problem, and this must be taken into account with determinations obtained by the use of the calculator. Addition of scales necessary to accomplish this would unduly complicate the instrument; however, it is usually desired to determine the vertical pattern in only certain specific directions, and formulas for calculating the radiation are available from several sources.[4,8]

For values of $kd$ between 180 and 360 degrees, two nulls may be obtained on each side of the line of towers. (Fig. 8.) The angles at which these nulls are obtained are labeled $\phi_1$ and $\phi_2$, with $\phi_1$ the larger. In addition to being determined from the calculator, the parameters for an array having nulls at the desired values of $\phi_1$ and $\phi_2$ may be determined from the formulas:

[8] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Company, New York 18, N. Y., 1943, p. 803.

$$kd = 360 \text{ degrees}/(\cos\phi_2 - \cos\phi_1) \quad (5)$$

$$\angle a = 180 \text{ degrees} - kd\cos\phi_2 = -180 \text{ degrees} - kd\cos\phi_1. \quad (6)$$

## Application to More than Two Elements

With the use of a different type of resultant vector scale, the calculator may assist in determining the horizonal field pattern of an array consisting of more than two elements. An array of this type may be thought of

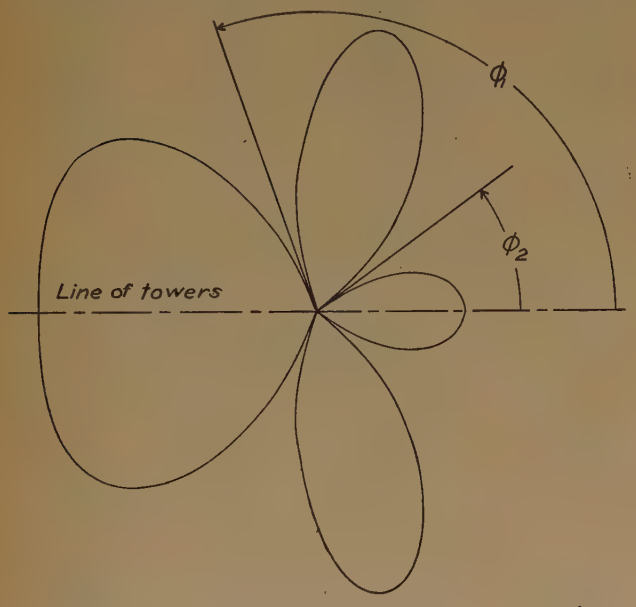



Fig. 8—Double nulls obtainable when 360 degrees $> kd >$ 180 degrees, and $ET_2/ET_1 = 1$.

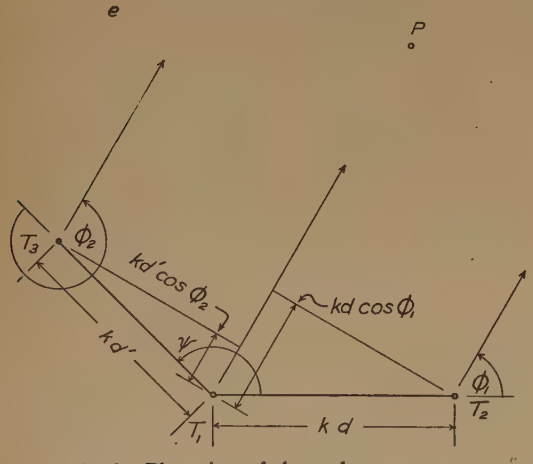



Fig. 9—Plan view of three-element array.

as a group of two-element arrays, with one element common to all such arrays. This common, or reference, element, labeled $T_1$, is the one producing the largest field component vector ($ET_1$). With a resultant scale calibrated to give the resultant vector $E_R$ in rectangular co-ordinate form, $E_R\cos\beta \pm jE_R\sin\beta$ (where $\beta$ is the angle between vectors $ET_1$ and $E_R$), a number of vectors occurring at any point in the field may readily be added.

Because the reference vector $ET_1(=1+j0)$ is common to all two-element arrays considered, it appears in the sum once too often for each such two-element array considered after the first. Hence, in determining the field strength at any point in the field of an array consisting of a total of $N$ elements, $(N-2)ET_1(=N-2+j0)$ must be subtracted from the sum of the resultant vectors at that point.

Fig. 9 indicates a three-element array with the elements not in line, and Fig. 10 indicates the vector combinations resulting at point $P$. In using the calculator in this way, care must be taken that the lines of direction to point $P$ coincide for the different two-element arrays. Thus, in Fig. 9, $\phi_2 = \phi_1 + 360 \text{ degrees} - \psi$. However, because a *two-element* array is symmetrical about the line of towers, $\phi_2$ may also be taken equal to $\psi - \phi_1$.

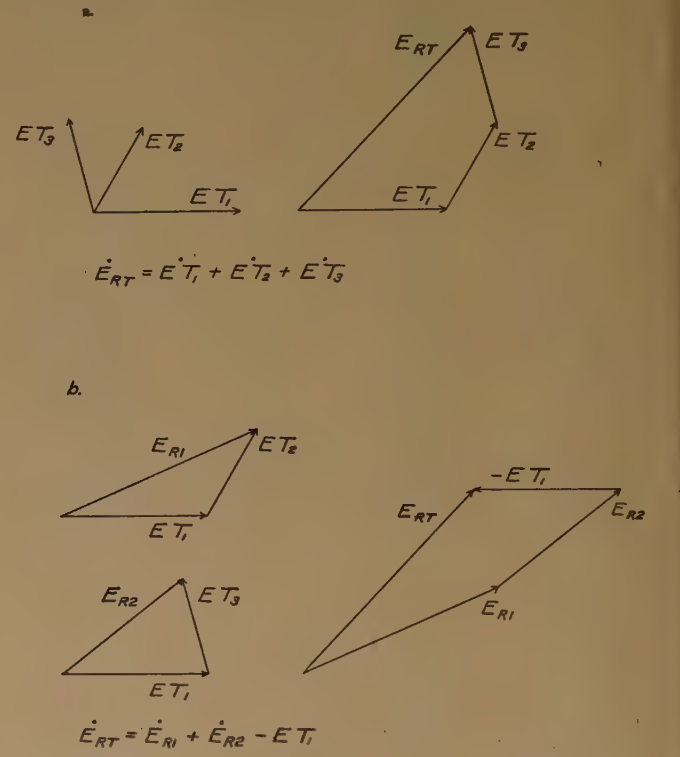



Fig. 10—Vector combination at point $P$ of Fig. 9. a. Combination of three vectors directly; b. Combination of vectors when array is considered to consist of two two-element arrays, with $T_1$ common to both.

The necessity for providing two resultant scales instead of one would tend to make this portion of the calculator somewhat difficult to read, if resultants were scaled for a large number of values of $ET_2/ET_1$. In the supplementary rotary element illustrated in Fig. 11, only the values for $ET_2/ET_1 = 1$ are scaled. In a calculator designed for an existing array, it would be necessary to provide scales for only existing field ratios and the corresponding 5 per cent unbalance.

The scales may be calculated as follows: (Refer to Fig. 6.)

$$ET_1 = E_R\cos\beta + ET_2\cos(180 \text{ degrees} - \overline{a + kd\cos\phi}) \quad (7)$$

$$\cos(a + kd\cos\phi) = (E_R\cos\beta - ET_1)/ET_2 \quad (8)$$

$$\text{and } ET_2/\sin\beta = E_R/[\sin(180 \text{ degrees} - \overline{a + kd\cos\phi})] \quad (9)$$

$$\sin(a + kd\cos\phi) = (E_R\sin\beta)/ET_2. \quad (10)$$

When $ET_2 = ET_1 = 1$,

$$\cos(a + kd\cos\phi) = (E_R\cos\beta) - 1 \quad (11)$$

and $$\sin (a+kd\cos\phi) = E_R \sin\beta. \quad (12)$$

These formulas are most useful in the forms shown in (8) and (10), for in these forms, central angles $(a+kd\cos\phi)$ may readily be determined for desired decimal values of $E_R\cos\beta$ and $E_R\sin\beta$. Scales on this supplementary rotary element are calibrated in a manner similar to that described for the calibration of scales on the regular rotary element. Tables XII and XIII give the central angles used in calibrating the resultant scales illustrated in Fig. 11. The negative "$j$" terms are those

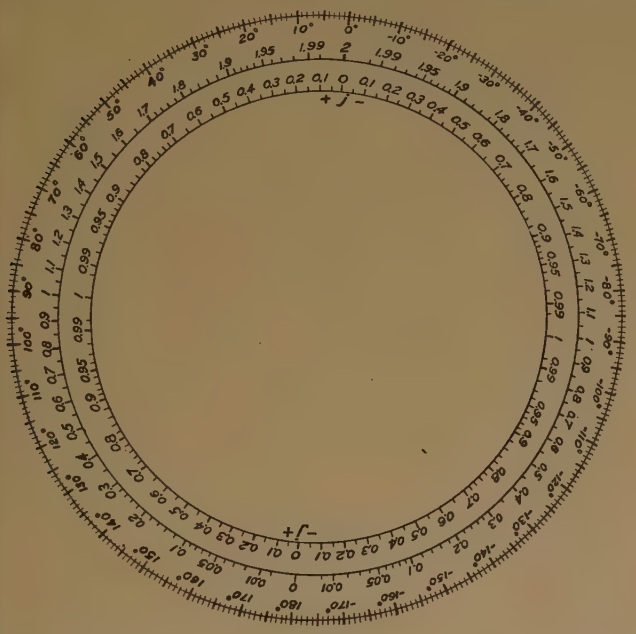


Fig. 11—Supplementary rotary element for use in calculating horizontal patterns of arrays consisting of more than two elements.

scaled in the two quadrants in which the phasing angles ($\angle a$ scale) are negative.

## Accuracy and Limitations

The accuracy of this instrument will depend largely upon the care taken in its construction and operation. Generally, the larger the instrument, the greater will be the accuracy and ease of operation obtained. With a carefully constructed instrument of convenient size, an accuracy to three significant figures or better should be obtained.

As indicated, this calculator, in the form described, is limited to determination of the horizontal pattern and gives no information regarding the vertical pattern. The instrument is not used by the Federal Communications Commission for allocation problems.

TABLE XII

Central Angles for Calibration of Resultant Vector Scale in Rectangular Co-ordinate Form. Real Terms for $ET_2/ET_1=1$.

| $E_R\cos\beta$ | $a+kd\cos\phi$ | $E_R\cos\beta$ | $a+kd\cos\phi$ | $E_R\cos\beta$ | $a+kd\cos\phi$ |
|---|---|---|---|---|---|
| | Degrees | | Degrees | | Degrees |
| 2.00 | 0.000 | 1.55 | 56.633 | 0.35 | 130.541 |
| 1.995 | 5.734 | 1.50 | 60.000 | 0.30 | 134.427 |
| 1.99 | 8.108 | 1.45 | 63.256 | 0.28 | 136.054 |
| 1.98 | 11.478 | 1.40 | 66.422 | 0.26 | 137.732 |
| 1.97 | 14.069 | 1.35 | 69.509 | 0.24 | 139.464 |
| 1.96 | 16.260 | 1.30 | 72.542 | 0.22 | 141.261 |
| 1.95 | 18.194 | 1.25 | 75.523 | 0.20 | 143.130 |
| 1.94 | 19.948 | 1.20 | 78.463 | 0.18 | 145.084 |
| 1.93 | 21.565 | 1.15 | 81.373 | 0.16 | 147.140 |
| 1.92 | 23.074 | 1.10 | 84.261 | 0.14 | 149.316 |
| 1.91 | 24.495 | 1.05 | 87.135 | 0.12 | 151.642 |
| 1.90 | 25.842 | 1.00 | 90.000 | 0.10 | 154.158 |
| 1.88 | 28.358 | 0.95 | 92.865 | 0.09 | 155.505 |
| 1.86 | 30.684 | 0.90 | 95.739 | 0.08 | 156.926 |
| 1.84 | 32.860 | 0.85 | 98.627 | 0.07 | 158.435 |
| 1.82 | 34.916 | 0.80 | 101.537 | 0.06 | 160.052 |
| 1.80 | 36.870 | 0.75 | 104.477 | 0.05 | 161.806 |
| 1.78 | 38.739 | 0.70 | 107.458 | 0.04 | 163.740 |
| 1.76 | 40.536 | 0.65 | 110.491 | 0.03 | 165.931 |
| 1.74 | 42.268 | 0.60 | 113.578 | 0.02 | 168.522 |
| 1.72 | 43.946 | 0.55 | 116.744 | 0.01 | 171.892 |
| 1.70 | 45.573 | 0.50 | 120.000 | 0.005 | 174.266 |
| 1.65 | 49.459 | 0.45 | 123.367 | 0.000 | 180.000 |
| 1.60 | 53.130 | 0.40 | 126.870 | | |

TABLE XIII

Central Angles for Calibration of Resultant Vector Scale in Rectangular Co-ordinate Form. $J$ Terms for $ET_2/ET_1=1$.

| $E_R\sin\beta$ | $a+kd\cos\phi$ | | $E_R\sin\beta$ | $a+kd\cos\phi$ | |
|---|---|---|---|---|---|
| | Degrees | Degrees | | Degrees | Degrees |
| 0.00 | 0.000 | 180.000 | 0.78 | 51.261 | 128.739 |
| 0.05 | 2.865 | 177.135 | 0.80 | 53.130 | 126.870 |
| 0.10 | 5.739 | 174.261 | 0.82 | 55.084 | 124.916 |
| 0.15 | 8.627 | 171.373 | 0.84 | 57.140 | 122.860 |
| 0.20 | 11.537 | 168.463 | 0.86 | 59.316 | 120.684 |
| 0.25 | 14.477 | 165.523 | 0.88 | 61.642 | 118.358 |
| 0.30 | 17.458 | 162.542 | 0.90 | 64.158 | 115.842 |
| 0.35 | 20.491 | 159.509 | 0.91 | 65.505 | 114.495 |
| 0.40 | 23.578 | 156.422 | 0.92 | 66.926 | 113.074 |
| 0.45 | 26.744 | 153.256 | 0.93 | 68.435 | 111.565 |
| 0.50 | 30.000 | 150.000 | 0.94 | 70.052 | 109.948 |
| 0.55 | 33.367 | 146.633 | 0.95 | 71.806 | 108.194 |
| 0.60 | 36.870 | 143.130 | 0.96 | 73.740 | 106.260 |
| 0.65 | 40.541 | 139.459 | 0.97 | 75.931 | 104.069 |
| 0.70 | 44.427 | 135.573 | 0.98 | 78.522 | 101.478 |
| 0.72 | 46.054 | 133.946 | 0.99 | 81.892 | 98.108 |
| 0.74 | 47.732 | 132.268 | 0.995 | 84.266 | 95.734 |
| 0.76 | 49.464 | 130.536 | 1.000 | 90.000 | 90.000 |

## Acknowledgment

The author gratefully acknowledges comments made by Mr. C. M. Daniell, consulting radio engineer, regarding pattern calculators in general. Appreciation also is expressed for the assistance rendered by the author's colleagues in suggesting certain revisions in this article.

# Institute of Radio Engineers to

The Board of Directors of the Institute has appointed a Building Fund Committee and will soon inaugurate a campaign to raise, among the members of the Institute, their well-wishers, and corporate friends, a sum of money "to be used in connection with the establishment of a suitable headquarters building, whether alone or in association with other engineering societies, as the opportunity presents." Further particulars will appear in subsequent issues of the PROCEEDINGS, and otherwise be brought to the attention of the membership.

The growth of membership, scope, and influence of the Institute warrants such a step at this time. From small beginnings, ours has become one of the major international engineering societies. It is in keeping with our present activities and attainments and our prospective needs and usefulness to the radio-and-electronic industries that we should be permanently housed.

The present membership of the Institute is over 12,000, representing almost 100% increase over that of 1940. From Fig. 1 which is reproduced with this article from the Report of the Secretary for 1943 and from a consideration of the history of the radio-and-electronic industries may be deduced the reasonable expectation that there will be rapid expansion with the advent of peace. There is reason to believe that electronics applications to industry after this war will reach something of the avalanche proportions of radio applications after World War I. The surrounding circumstances are the same: war-stimulated research, undercover infiltration of advanced technology waiting to burst its bonds, unsatisfied consumer demand, pent-up buying power, and a new generation of youthful enthusiasm and experience to be released from the Armed Services. The expansion of electronic controls and electronic power to industry can be clearly discerned; so can the expansion of television, frequency modulation, radar, wide-band coaxial cable and radio relay communication systems and other as yet undisclosed devices and fields. Hidden from all our plans, as the enormous radio broadcasting development of the '20's was hidden from the research engineers of the first World War, is the precise form that a parallel development may take in the late '40's and early '50's. That the development will come we may argue by analogy. That the activities of the Institute will be fundamentally necessary to it, this time as it was last, is no less certain.

If the Institute is to grow with the industry and the civilization it serves, it must promptly take on and meet the increased responsibilities which go with growth. With removal of paper restrictions and the release of military inhibitions on certain types of publication, the PROCEEDINGS will become more voluminous. As the field of electronic applications mushrooms out, our publication scope must and will widen to match it, for only by comprehensive publication service may the Institute expect to serve the whole radio-and-electronic field and remain a cohesive force in tying the myriad applications to fundamental scientific research and measurement. The Institute must also continue to serve the professional interests of its engineering members, to make its voice heard in standardization work, in government

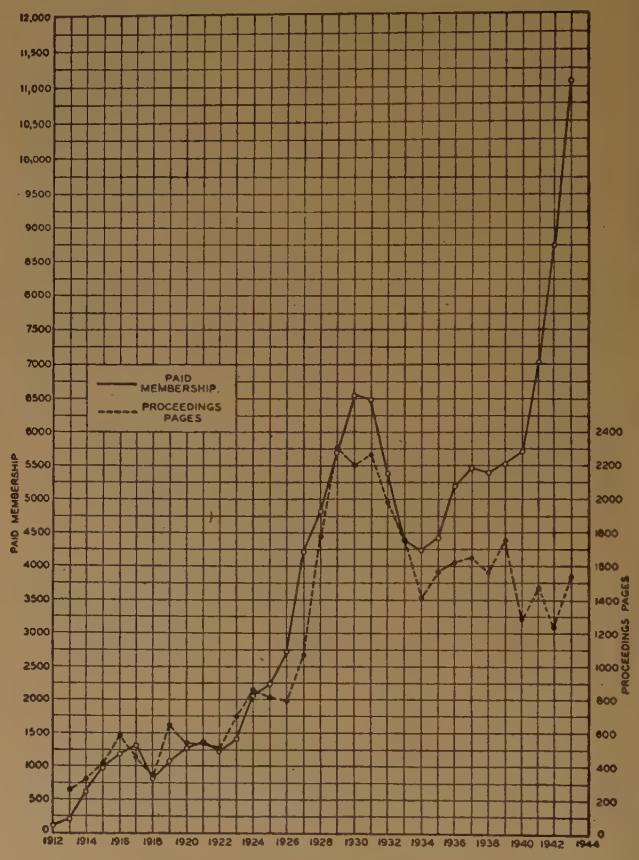



FIG. 1—The variation in paid membership is shown by the solid graph. The dotted line is for the number of pages of technical and editorial material in the PROCEEDINGS. Starting in 1939, a larger format was used and the scale of pages should be divided by 2.2.

counsel, in professional and labor circles. The future communication engineers and electronic engineers need their Institute.

All this, as a practical matter, translates in part into more staff and more office space. In the opinion of the Board of Directors, the half-way measure of hiring larger quarters is not the answer. The Institute should obtain in the near future a building, suited to the functional needs of the Institute, of a dignity in keeping with its prestige, and large enough for its prospective needs over a long period of years.

# Act to Secure a Permanent Home

During the past year the Board has been active in visiting sites and investigating the possibilities, and is continuing its explorations. Although recognizing the tremendous advantage of being able to go before the membership and other prospective donors with a photograph or architectural drawing of the building which it might intend to purchase or erect, final determination of the course to be pursued has had to be left open for the unfolding of events. The present is considered a favorable time to secure funds, so much so that if the opportunity is allowed to pass, it may not occur again. In these circumstances, when the campaign is launched, it will have as an objective a sum which will afford leeway for making one of several different possible moves, including immediate occupancy of a permanent building; purchase of temporary quarters or rental looking forward to postwar ownership or erection of a permanent building; joining with the Founder Societies or with other engineering or scientific organizations in co-operative home ownership. Appropriate additional conditions will surround and safeguard the funds which are secured.

The following brief history of Institute quarters, culminating in the present crowded conditions, will give point to the needs:

When The Institute of Radio Engineers was founded on May 13, 1912, by the amalgamation of the Wireless Institute in New York City and the Society of Wireless Telegraph Engineers in Boston, its membership was less than fifty. It had no real office headquarters for many years, for its business was conducted from private offices at 71 Broadway and 111 Broadway, New York, until 1918, when Dr. Alfred N. Goldsmith, who carried the dual burden of Secretary and Editor, discharged these duties from his offices at the College of the City of New York.

In the spring of 1924 a small suite of offices was leased at 37 West 39th Street in New York City, and the Institute had its first real headquarters. The organization was growing in such a healthy manner that in January, 1927, it was necessary to employ a full-time Assistant Secretary and a small clerical staff to handle the volume of work. In the early winter of 1928, that space was outgrown, so larger and more spacious quarters were rented in the Engineering Societies Building at 33 West 39th Street. The staff again was enlarged and included a full-time Secretary, Assistant Secretary, Assistant Editor, Circulation Manager, Advertising Manager, and Head Bookkeeper. The space in the Engineering Societies Building was adequate for a few years, but in the spring of 1934 it was necessary to move again, this time to the McGraw-Hill Building at 330 West 42nd Street. In the winter of 1942, that suite proved to be too small and the Institute was moved, in the same building, to the larger but now inadequate quarters which it occupies at the present time.

Due to rapid growth of Institute activities, and even before expiration of the present favorable lease, we are faced with the problem of once more finding enough space to do our work. The Directors formerly had a crowded Board Room which it shared with Committees for their activities, including frequent meetings of the important Executive Committee, but that has been sacrificed to take care of the bookkeeping department, whose increase in work is roughly proportional to expanding membership. The Board and all the standing and technical committees now are forced to meet in rooms rented by the day, except when a small table in the Assistant Secretary's office will accommodate a few persons, to the detriment of our principal paid officer's work. The President has no office, nor has the Editor, the Secretary, or the Treasurer, even on a shared basis, in spite of their frequent and necessary visits to the office. The Advertising Manager, his office and staff, moved out of the suite some months ago to release needed space to others. The addressograph room is overcrowded. The files are split between the Institute office and other space some distance away. The Associate Editor and Office Manager have tiny cubicles, but the stenographic and clerical force are so badly cramped that carrying on special jobs like Radio Technical Planning Board cooperation, preparation of Yearbooks, and detail work of conventions severely cramps the staff. It must be borne in mind that when the several moves were made, prudent allowance was made for expansion, but the combination of numerical growth and broadening of scope of activity has far outrun all reasonable estimates.

The prospect of moving as often as in the past is unattractive. To acquire a really adequate floor area, such as there is in a building made to suit our functions, is so expensive as to indicate the advisability of purchasing.

The American Institute of Physics bought its own home about a year ago and has found it most satisfactory. The four Founder engineering societies, The American Institute of Electrical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, and The American Society of Mining and Metallurgical Engineers have had their own home for about thirty years in the Engineering Societies Building and have found the co-operative arrangement well suited to their purposes. One or the other of these plans is within I.R.E.'s capacity to undertake, and, in the opinion of our Board, should be undertaken forthwith.

# Institute News and Radio Notes

## Board of Directors

***October 4 Meeting:*** At the regular meeting of the Board of Directors, which was held on October 4, 1944, the following were present: H. M. Turner, president; R. A. Hackbusch, vice-president; S. L. Bailey, W. L. Barrow, E. F. Carter, I. S. Coggeshall, W. L. Everitt, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; H. J. Reich, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

***Constitutional Amendments:*** The first ballot on Constitutional Amendments was mailed, in accordance with the recommendation of the Executive Committee, on September 15, 1944, to the entire voting membership. It is planned to mail another ballot, to be on the petitioned amendment of Article IV, after the results of the first ballot indicated become known.

The second ballot will contain a statement of H. P. Westman, from whom the petition had been received, and another statement signed by President Turner. A notice of the second ballot is also scheduled to appear in the December issue of the PROCEEDINGS.

*Conferences*

*National Electronics Conference:* A report on this conference was given by President Turner and followed by the discussion and actions indicated below:

Editor Goldsmith recommended that the Institute increase its support of this conference and pointed out that there is no duplication of interest or effort between the Institute's Electronics Conference, which is devoted primarily to theory, and the NEC. It was also suggested that the NEC could be expanded to be international in scope.

*Broadcast Engineering Conference:* It was the general opinion that a policy, similar to that outlined for the National Electronics Conference, would be desirable in case of the Broadcast Engineering Conference, of which the fifth and last meeting was held on February 23–27, 1942.

***Canadian I.R.E. Council:*** These matters, concerning the Canadian membership of the Institute, were reported by Vice-President Hackbusch, and discussed and acted upon as shown below:

*Canadian Radio Technical Planning Board:* The progress of the CRTPB was described and it was proposed that the Institute consider making a contribution to the Canadian I.R.E. Council for the expense involved in carrying on the named Board's activities.

After discussing the Proposal, a suitable contribution was unanimously authorized, to be made through the Canadian I.R.E. Council, for the Canadian Radio Technical Planning Board work during the year beginning October, 1944.

*Canadian Engineers' Council:* It was stated that the Canadian Engineers' Council is in process of formation and would serve to represent the Canadian engineering and scientific bodies on matters relating to legislation, postwar planning, collective bargaining, and the Wartime Bureau of Technical Personnel in the Dominion.

*Proceedings*

*Papers Procurement:* Editor Goldsmith was authorized to send a double postal card to all members including Students, for the purpose of determining the papers that could be submitted now or in the near future, and those soon after the end of the war.

*Papers Procurement Committee:* The appointment of V. J. Young to the Timers and Technical Controls Group was unanimously approved.

*Postwar Publication Fund:* On recommendation of the Executive Committee, unanimous approval was given to increasing the reserve fund for postwar publications from $14,000 to $20,000 and to depositing the fund in a separate account as suggested by the auditor.

*Tutorial Papers:* The resumption of tutorial papers was suggested and it was noted that a number of members are in favor of having the PROCEEDINGS publish good papers of this type. The following motion resulted from the discussion:

> "The Board is sympathetic to having the PROCEEDINGS publish outstanding tutorial papers whose presentation quality exceeds that of the average original papers."

***1945 Winter Technical Meeting:*** In behalf of the Executive Committee, Mr. Wheeler reviewed the budget, program, and personnel of the General Committee for this meeting, which is scheduled to be held on January 24–27, 1945, at the Hotel Commodore, in New York.

The WTM activities, recommended in the September 28, 1944, letter from Austin Bailey, chairman of the WTM General Committee, were approved.

*Annual Meeting:* Upon the recommendation of the Executive Committee, it was decided to hold the Annual Meeting of the Institute during the half-hour interval between 10:00–10:30 A.M. on January 25, 1945, and as part of the 1945 Winter Technical activities at the Hotel Commodore, New York City.

***Indianapolis Section:*** Mr. Wheeler reported on the request of the Indianapolis Section, made in the September 25, 1944, letter from Section Chairman H. I. Metz, for permission to affiliate with the Indianapolis Technical Societies Council. The constitution of the Council was discussed and it was noted that no dues are required of the member societies.

The motion, granting permission to the Indianapolis Section to become affiliated with the named Council, was approved by an unanimous vote.

***Radio Technical Planning Board:*** In behalf of Secretary Pratt, the Institute's Representative on the RTPB, Dr. Barrow, as Alternate, reviewed briefly the meetings of the RTPB and its Administrative Committee which were held in September. These matters were discussed and it was decided that the Institute continue its support of the RTPB.

***ASA Committee on Radio Noise:*** Mr. Wheeler, chairman of the Standards Committee, reported on the proposed ASA War Standards Committee on Methods of Measuring Radio Noise, which is in the process of organization.

After a discussion, the following members were appointed to the committee in the capacities indicated:

H. B. Fischer, Representative
C. J. Franks, Alternate
Garrard Mountjoy, Alternate

## Executive Committee

***October 3 Meeting:*** The following members were present at the October 3, 1944, meeting of the Executive Committee: H. M. Turner, president; E. F. Carter, Alfred N. Goldsmith, editor; R. A. Heising, treasurer; F. B. Llewellyn, H. A. Wheeler, and W. B. Cowilich, assistant secretary.

***Membership:*** The following applications for membership were approved: for transfer to Senior Member grade, N. G. Anton, R. E. Beam, P. S. Christaldi, C. W. Corbett, L. T. DeVore, W. E. Donovan, F. A. Everest, D. G. Grieg, Samuel Gubin, K. G. MacLean, D. E. Noble, E. M. Ostlund, Simon Ramo, G. H. Scheer, Jr., J. F. Wentz, and J. W. Wright; for admission to Senior Member grade, V. W. Sherman, and O. S. Duffendack; for transfer to Member grade, M. E. Campbell, F. M. Deerhake, H. H. Edwards, H. E. Ellithorn, W. D. Espy, Manuel Fernandes, Leroy Fiedler, D. P. Gorman, A. W. Graf, O. C. Hirsch, H. S. McCartney, W. O. Sharp, P. W. Sokoloff, E. G. Squires, Harry Stockman, H. P. Thomas, T. S. Wang, and R. H. Williamson; for admission to Member grade, R. C. Curtis, F. M. Davis, Rudolf Feldt, A. H. Hackett, W. A. Laning, S. W. Norman, A. W. Warner, Jr., A. C. Weid, and Saul Weissman; Associate grade, 111; and Student grade, 30.

***Petitioned Constitutional Amendment:*** Chairman Heising, as Constitution and Laws Committee Chairman, called attention to several matters relating to the petitioned amendment of Article IV, mentioned below:

Petition to Amend Article IV. These matters have been scheduled with reference to a separate ballot on the petitioned constitutional amendment:

(1) A separate ballot to be sent after the returns from the first constitutional-amendment ballot, mailed on September 14, 1944, have become known.
(2) A notice of the additional constitutional-amendment ballot to be published in the December issue of the PROCEEDINGS.
(3) The ballot on the petitioned

amendment to include a statement from H. P. Westman, from whom the petition had been received, and another statement signed by President Turner.

***National Electronics Conference:*** The plans for this conference, scheduled to be held this month at Chicago, were considered to be progressing favorably and it was stated that many Institute members are planning to attend.

The suggestion was made to Mr. Wheeler that steps be taken to encourage the continuation of this conference, of which the Institute's Chicago Section is one of the sponsors.

***Audit Bureau of Circulations:*** The circulation statements for the PROCEEDINGS covering the first six months of 1944, recently prepared and submitted by the Institute office, has been officially released by the A.B.C. Attention was called to monthly-average increases, indicated below:

| | January-June 1944 | July-December 1943 | January-June 1943 |
|---|---|---|---|
| Total Distributions | 13,348 | 11,754 | 10,427 |
| Paid Memberships (excluding Students) | 9,640 | 8,276 | 7,443 |
| Paid Students | 2,259 | 2,101 | 1,543 |
| Paid Subscriptions | 1,076 | 1,039 | 900 |

***Ottawa Section:*** Mr. Wheeler reported that the Montreal Sections had agreed on the territory of the Ottawa Section, outlined below:

Counties in Ontario: Lennox and Addington, Renfrew, Lanark, Frontenac, Leeds, Carleton, Grenville, Dundas, Stormont, Glengary, Prescott, and Russell.

Electoral Districts in Province of Quebec: Pontiac, Hull, and Laval (Labelle).

It was further stated that the decision of the Montreal and Toronto Sections on the defined area, including proposals of the three Sections involved, had been communicated to the Ottawa Section, and that the reply of the latter Section is expected in the near future.

***Technical Committees:*** Dr. Llewellyn pointed out that the technical committees are becoming more active and that consequently the need now exists for a full-time technical secretary to co-ordinate the work of these groups as had been done previously.

After a favorable discussion, it was decided to defer further consideration of the matter to the next meeting.

***Propagation Data:*** In his capacity on the Executive Committee, Dr. Llewellyn called attention to a September 26, 1944, letter from W. R. G. Baker suggesting that the Institute co-ordinate available propagation data above 300 megacycles and release the information to the profession and to industry.

As a result of the discussion, it was moved to refer Dr. Baker's letter to Chairman C. R. Burrows of the Radio Wave Propagation Committee, with the suggestion that the committee take the action proposed by preparing a report and/or by having suitable papers submitted for publication in the PROCEEDINGS.

***Subscriptions:*** It was the opinion that the subscription data on the *Journal of the Institution of Electrical Engineers* (England) should be publicized in the PROCEEDINGS each month for a year, that such information should include the regular rates, and that those interested should be directed to make their remittances to the London address of that journal.

It was further decided to submit subscription data on the PROCEEDINGS for publication in the *Journal of the I.E.E.* on a similar basis.

The Assistant Secretary was instructed to send the PROCEEDINGS data to Mr. W. K. Brasher, Secretary of the I.E.E. and to request similar data on their journal for use in the PROCEEDINGS.

## Constitutional-Amendment Section

By the time this issue of the PROCEEDINGS reaches the membership, the ballots on the Constitutional Amendments sent out in September will have been counted. The result of the ballot will appear in the January issue.

In the meantime, plans are under way to submit to a vote the proposed Constitutional Amendment submitted by petition in August by Mr. Westman and other members. The voting membership may expect to receive their ballots on this amendment a short time after the appearance of this notice.

As stated in earlier issues of the PROCEEDINGS the aim of these amendments is to establish a system of dues that will facilitate the classification of members into grades commensurate with their qualifications without imposing a financial obligation which at present is regarded by some as a serious deterrent to proper classification. Discussions of the proposed amendment will be transmitted to the voting membership along with the ballot. In the meantime, those interested will find the subject presented in the following issues of the PROCEEDINGS:

September, 1944, p. 567, letter from Mr. Westman; also p. 562 paragraph No. 10;

October, 1944, p. 639; November, 1944, p. 713 under Board of Directors.

R. A. HEISING, *Chairman*
Constitution and Laws Committee

## 1945 Winter Technical Meeting

Early response from the radio engineers and industry confirms the belief of the general committee in charge of the coming Winter Technical Meeting that attendance at the four-day sessions, January 24–27, will reach a new high in I.R.E history.

Many problems must be met and solved by the various subcommittees because of wartime conditions but none is more critical than that of hotel reservations for out-of-town guests. With the opening date only a few weeks away, it is essential that members who will be present reserve their rooms at once. The hotel situation in New York has been complicated during the last month by a set-aside order to care for military personnel and their families but I.R.E. visitors can be accommodated if reservations are made at once.

The papers committee has announced that papers already in hand insure an interesting program. It is believed that a fairly complete agenda of the sessions will be available for the January issue of the PROCEEDINGS.

The Papers Committee has made a determined attempt to obtain papers that will be expressive of postwar problems and developments as well as of wartime technical activities. In hopes that the favorable progress of the war will relax present restrictions on certain electronic devices now playing a vital role in military maneuvers, the committee will hold open a certain amount of time for last-minute manuscripts.

It has already been planned to devote special sessions to the radio aspects of the industrial-electronics field, to recent advances in vacuum-tube theory and development, and to radio links and relays. The latter subject is a particularly live one now, with television and frequency modulation occupying the thoughts of postwar planners on mass communications.

From all indications the exhibits will be one of the most important features of the Winter Technical Meeting. The number of firms that already have requested display space is so much greater than the committee first estimated that additional room is being sought on the convention floor. Here, also, it is hoped that secrecy surrounding many war devices will be dropped sufficiently to permit the exhibition of some war equipment.

As explained in the November PROCEEDINGS the general committee has recognized the desire of convention guests for social meetings between sessions. The "cocktail party" on the evening of January 26 is only one of the social high spots. Special arrangements will be made to entertain the ladies who come to New York for the meeting. Details of these attractions should be completed in time for an announcement in the January issue.

## National Electronics Conference

Attracted by a program of fifty outstanding technical papers on all branches of technical developments in electronics, 2191 engineers, scientists, and technical workers were officially registered and took part in the technical meeting, banquet, and luncheons of the first National Electronics Conference at the Medinah Club of Chicago on October 5, 6, and 7. While the majority of those attending the Conference were from the United States, representatives from government or commercial agencies of Argentina, Canada, China, England, France, Mexico, and Russia were also present. The most prominent Canadian representative was Ralph A. Hackbusch, vice-president of

The Institute of Radio Engineers. Other members of the I.R.E. Board of Directors who attended the conference were H. M. Turner, president; F. B. Llewellyn, A. B. Chamberlain, I. S. Coggeshall, H. J. Reich, E. F. Carter, and H. A. Wheeler.

After an address of welcome by O. W. Eshbach, dean of the Technological Institute, Northwestern University, the Conference was opened by Ralph R. Beal, assistant to the vice-president in charge of RCA Laboratories, who spoke on "Electronic Research Opens New Frontiers." In this address, the many possibilities for future developments in the field of electronics were ably outlined.

At the luncheon on Thursday, October 5, W. C. White, director of the electronics laboratory, General Electric Company, spoke on "Electronics in Industry." The many industrial applications of electron tubes, first extensively developed by communications engineers, were high-lighted in Mr. White's address. This luncheon was arranged by the Chicago Section of the American Institute of Electrical Engineers and R. C. Ericson, chairman of the Chicago Section, presided.

At the banquet on Thursday evening at which H. T. Heald, president of the Illinois Institute of Technology presided, there were 1185 guests. Electronic-wire recordings of five-minute talks by Rear Admiral Joseph R. Redman, Director of Naval Communications, and Major General H. C. Ingles, Chief Signal Officer, were heard. The topic of both talks was "What Electronics Has Meant to the Armed Forces."

The banquet address, "Triggers to Mass Actions" was given by Major Lenox Lohr, president of the Museum of Science and Industry. In this address, Major Lohr discussed certain factors which are responsible for concerted action of large groups of persons. This address was followed by a program of entertainment.

At the Friday luncheon, arranged by the Chicago Section of the I.R.E., at which W. O. Swinyard, chairman of the Chicago Section presided, all members of the Board of Directors who attended the Conference were honored guests. Professor Turner commented on the excellent program of technical papers, the evident interest in noncommunication topics, and the large attendance which exceeded that of any I.R.E. or A.I.E.E. technical meeting. Professor Turner also expresed the desire of the Institute to co-operate more fully with the Conference in its future meetings.

Friday evening an informal dinner-meeting was held to enable members of the Board of Directors to become better acquainted with I.R.E. members prominent in the activities of the Chicago Section. Those at this dinner included W. O. Swinyard, chairman of the Chicago Section, presiding; H. M. Turner, president of the Institute; Ralph A. Hackbusch, vice-president; F. B. Llewellyn, Kenneth Jarvis, A. B. Chamberlain, Alfred Crossley, A. B. Bronwell, H. C. Luttgens, L. E. Packard, D. E. Foster, V. J. Andrew, I. S. Coggeshall, A. W. Graf, secretary of the Chicago Section; Cullen Moore, vice-chairman of the Chicago Section; A. H. Brolly, Paul Smith, H. J. Reich, R. H. Herrick, E. F. Carter, H. A. Wheeler, and Beverly Dudley. B. E. Shackelford was present for a few moments, but a previous engagement prevented him from taking part in the discussion.

At the I.R.E. dinner-meeting, Mr. Wheeler reported that he had been commissioned by the Board of Directors to extend the whole-hearted co-operation of the national body of the Institute in furthering the activities of the National Electronics Conference. He expressed the hope that the Conference would call on the I.R.E. as a means of promoting common interests. It was pointed out by Mr. Swinyard that the Chicago Section of the I.R.E. had only a minority voice in the Executive Committee of the Conference, but that a sufficient number of Committee members was present to convey the Board's thoughts accurately. The meeting was then opened for discussion of methods of co-operation and general Institute matters. The principal topic of discussion was the need for expanding the field of interest of the I.R.E. in a definite and concrete way that would be immediately apparent to all members.

Perhaps the outstanding significance of the Conference, so far as the I.R.E. is concerned, is the unusually large attendance for a first meeting, indicative of the interest in all phases of electronics, and the appreciable interest in noncommunication topics. The following tabulation gives some indication of the topics covered by the sixteen technical sessions of the Conference. It also indicates the comparative interest in various topics as judged by attendance at the technical sessions.

| Technical Session | Approximate Attendance |
|---|---|
| 1. Television | 1000 |
| 2. Electronic Power Applications | 200 |
| 3. Electronic Aids to Medical Science | 100 |
| 4. Survey of Industrial Electronics | 350 |
| 5. Radio | 550 |
| 6. Electronic Measurements and Controls | 950 |
| 7. Recent Developments in Theoretical Electronics | 350 |
| 8. Electron-Tube Developments | 700 |
| 9. Industrial Applications; Electronic Devices | 600 |
| 10. Radio and Telephone Applications | 300 |
| 11. Ultra-High Frequencies | 600 |
| 12. High-Frequency Heating | 700 |
| 13. Industrial Radiography | 200 |
| 14. Aeronautical Applications | 110 |
| 15. Recent Developments in Electron Theory | 800 |
| 16. Industrial Applications | 300 |

Several hundred persons also attended educational motion pictures illustrating the principles of electronic devices or dealing with the manufacture of equipment.

The numerous expressions of interest for continuing the Conference and the success of the first meeting makes it possible to announce the holding of the second National Electronics Conference in Chicago in October, 1945.

BEVERLY DUDLEY

# Correspondence

Correspondence on both technical and nontechnical subjects from readers of the PROCEEDINGS OF THE I.R.E. is invited, subject to the following conditions: All rights are reserved by the Institute. Statements in letters are expressly understood to be the individual opinion of the writer, and endorsement or recognition by the I.R.E. is not implied by publication. All letters are to be submitted as typewritten, double-spaced, original copies. Any illustrations are to be submitted as inked drawings. Captions are to be supplied for all illustrations.

## Sources of Mica

September 6, 1944

To the Editor:

Dear Sir:

I have received a letter from Mr. H. W. Eckweiler, Industrial Specialist, Mica-Graphite Division, War Production Board, in which he calls attention to a misstatement regarding the mica for radio condensers from India, appearing in the second sentence of my paper "Equipment and method for measurement of power factor of mica," published in the July, 1944, issue of the PROCEEDINGS on pages 393–397. The objection is to the last clause in the following sentence as published, "A very large part of the mica used in this country for radio condensers has been obtained abroad in the past, from India in particular, but this supply has been practically eliminated." Mr. Eckweiler says that this clause is incorrect and thinks that a correction should be published.

Quoting from Mr. Eckweiler's letter of August 29:

"Prior to the war, our main sources of mica were India and Brazil, but due to increased use for war purposes, it became necessary to develop other sources and expand the existing sources of supply. Due to various factors, such as reluctance of the trade to use mica from untried sources, the demand for mica of Indian origin was greater than the supply. Hence, many felt that Indian imports were disappearing, although, in fact, they were increasing. It became necessary for consumers to use mica from other sources, domestic and foreign, where classification and grading was not up to the Indian standards in many instances. This has been corrected to a great degree, and today, mica from other sources is being used with complete satisfaction for most critical applications.

"We realize that much misinformation regarding mica has been circulated. This is probably due, in part, to the secrecy which has surrounded our mica programs. We, therefore, feel it desirable to correct the statement regarding the 'practical elimination of Indian imports.'

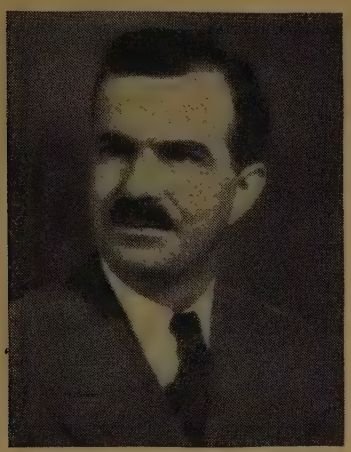
"I trust that you may be able to publish this in an early issue of the PROCEEDINGS in order to clear up any erroneous impression unintentionally created by the original statement."

Very truly yours,

E. L. Hall, Radio Engineer
National Bureau of Standards
Washington, D. C.

# Contributors

Carlyle M. Ashley was born on August 17, 1899, and received the M.E. degree from Cornell University in 1924. He was associated with the Telluride Association and



CARLYLE M. ASHLEY

with Carrier Engineering Corporation, Syracuse, New York, during 1916–1917, returning to that organization in 1924. He has remained there since that time, holding successive positions as test engineer, appliance engineer, project supervisor, and, at present, director of development.

Mr. Ashley has designed a wide range of air-conditioning equipment, including the Carrier Unit Air Conditioner, Carrier Safety Steam Ejector Railroad Air Conditioner, and a complete range of air-conditioning and refrigerating equipment. He is the holder of numerous patents. Mr. Ashley is a member of the American Society of Heating and Ventilating Engineers and of the American Society of Refrigeration Engineers.

❖

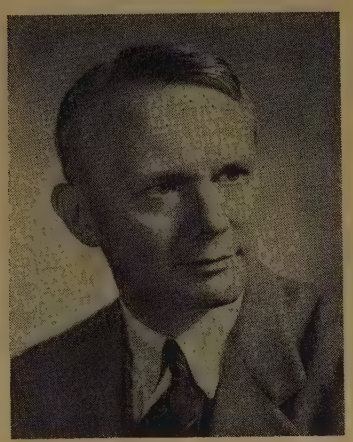
G. L. Beers (A'27–M'29–SM'43) was born at Indiana, Pennsylvania, in 1899. He received the B.S. degree in electrical engineering from Gettysburg College in 1921. Mr. Beers was in the graduate-student

G. L. BEERS

course and engineering school of Westinghouse from 1921 to 1922; in the radio engineering department of the Westinghouse Electric and Manufacturing Company, in charge of superheterodyne receiver development, from 1922 to 1930; section engineer in the research department of the RCA Manufacturing Company from 1930 to 1940; in charge of the advanced development division from 1940 to 1942; manager of the engineering and manufacturing service division 1942 to 1943; and since 1943 on the engineering administration staff.

❖

E. M. Guyer (A'32) was born at Cincinnati, Ohio, in 1900. He received the A.B., M.S., and Ph.D. degrees from the Uuiversity



E. M. GUYER

of Wisconsin in 1923, 1925, and 1929, respectively. From 1925 to 1929 he was assistant in the physics department at the University of Wisconsin, and engaged in research in geophysics and electrical prospecting.

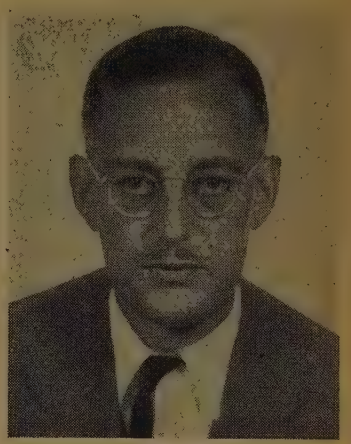
From 1929 to date, Mr. Guyer has been connected with the research and development division of Corning Glass Works, engaged in research on dielectrics and development work on methods and equipment for electrical glass working. He is the inventor of the Corning system of high-frequency electrical glass sealing.

Mr. Guyer is a member of Phi Kappa Phi, Gamma Alpha, Sigma Psi, the American Association for the Advancement of Science, and the American Physical Society.

❖

Leonard R. Malling (A'31) was born in Acton, England, on July 9, 1909. He received the E.E. degree from Northampton Technical Institute, in England. From 1927 to 1931 he was associated with the research laboratories of Electrical and Musical Industries, and thereafter devoted one year to work on the International Telephone and Telegraph links, followed by a year in instrument development with Marconi-Ecko Company.

From 1934 to 1938 Mr. Malling was engaged in television research with the Baird Television Company in England. In 1938 he engaged in work on television research



LEONARD R. MALLING

and electronic war developments for Hazeltine Electronic Corporation, New York, and from 1943 to 1944 was associated with the University of California division of war research. At the present time Mr. Malling is doing research in the physical research department of Boeing Aircraft Company, at Seattle, Washington.

❖

William H. Parker, Jr., (A'36) was born at Everett, Massachusetts, on August 7, 1906. He received his education at the Massachusetts Institute of Technology from 1925 to 1929, returning to that institution for graduate work in 1931 and 1932.

During 1929 and 1930 Mr. Parker was a member of the engineering staff of the Amrad Corporation. In 1935 he became an assistant radio engineer for the United American Bosch Corporation, and from 1936 to 1938 was a police radio engineer. He was employed as an engineer for Fada Radio and Electric Company from 1938 to 1941,

WILLIAM H. PARKER, JR.

and as a receiver design engineer for the Federal Telegraph Company in 1941 and 1942. Since that time he has been with the Stromberg-Carlson Company as project engineer.

❖

Horace O. Parrack was born in Preston County, West Virginia, on September 16, 1905. He received the A.B. degree in 1929 from the University of West Virginia. In 1932 he received the M.A. and in 1940 the Ph.D. in physiology from Columbia. He was

HORACE O. PARRACK

an instructor in zoology from 1929–1931 and instructor in physiology from 1934–1939 at Columbia. He was a Porter Fellow at Harvard during 1939–1940 and an Austin Teaching Fellow in Harvard Medical School in 1940. Dr. Parrack's research has been in electrophysiology. He is now a Captain in the Army of the United States.

❖

William M. Rogers was born in Jennings, Florida, on September 18, 1900. He received the B.S. degree from the University of Georgia in 1921 and, in 1927, the Ph.D. degree from Cornell University where he was an instructor from 1924 to 1927. During 1927 to 1928 he was an instructor in anatomy at University and Bellevue Medical College and from 1928 to 1931 an instructor at the College of Physicians and Surgeons, Columbia University. Dr. Rogers is now assistant professor of anatomy at Columbia where he is carrying on experimental research in neuroembryology and neurophysiology. One phase of this work has been the application of electronic apparatus to the study of peripheral nerve injuries.

WILLIAM M. ROGERS

❖

J. G. Rountree (A'39–M'44) was born in Bee County, Texas, on January 7, 1914. He received the B.A. degree with honors from the University of Texas in 1937, having majored in physics. During his senior year, he was employed by KNOW, Austin, Texas, and on graduation, he entered the employ of KTSA, San Antonio. In 1939, he was employed by WBAP, Fort Worth, and in September, 1941, he joined the field division of the engineering department of the Federal Communications Commission as radio inspector. From May, 1942, to November, 1943, he was attached to Headquarters New Orleans Air Defense Region as a civilian liaison officer.

J. G. ROUNTREE

❖

Mr. Rountree has been active in amateur radio circles since 1932, holding a license for amateur station W5CLP.

❖

SAMUEL SABAROFF

❖

Samuel Sabaroff (A'42) was born in Philadelphia, Pennsylvania, on November 10, 1908. In 1931 he received the B.S. degree in electrical engineering from Drexel Institute and in 1937 of the M.S. degree from the University of Pennsylvania. From 1931 to 1932 he was in the reject-control and factory laboratory of the Philco Radio and Television Corporation. Since 1932 Mr. Sabaroff has been a transmitter engineer with the WCAU Broadcasting Company. He is also employed as consultant in defense work.

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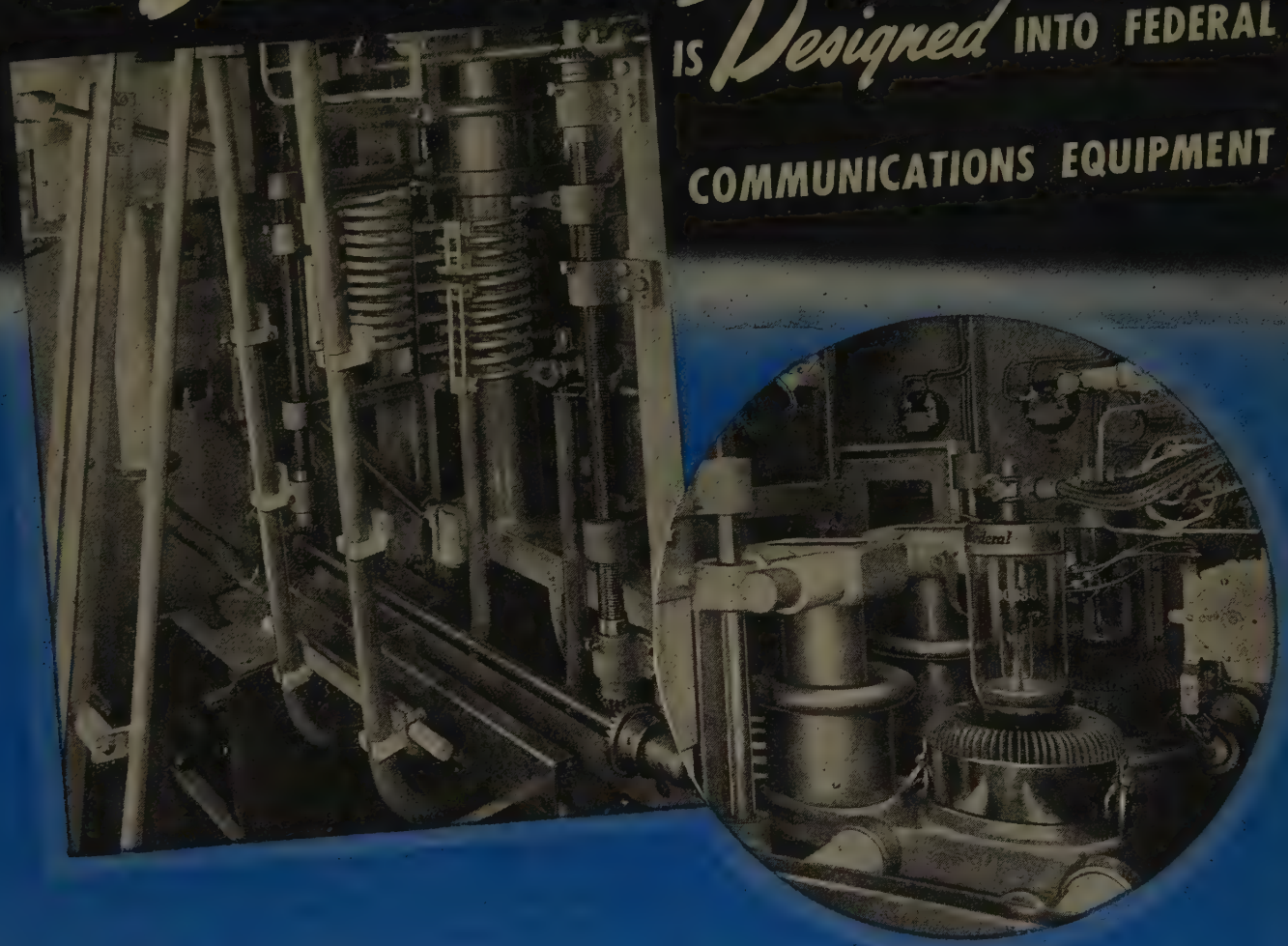

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"A Discussion on Radio Sonde in Forecasting," by D. W. Miller, United States Weather Bureau; May 19, 1944.

BOSTON

"Handling of Telegrams in Facsimile," by I. S. Coggeshall, Western Union Telegraph Company; March 17, 1944.

BUFFALO-NIAGARA

"Audio and Public-Address Work in Industry," by A. J. Dybowsky, Dymac, Inc.; February 28, 1944.

"Radio Communication and Photoelectric Controls in Power," by Herbert Stadermann, Buffalo Niagara Electric Corp.; February 28, 1944.

"The Magnetic Recorder," by W. R. David, General Electric Company; March 8, 1944.

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"The Electron Microscope," by L. P. Copeland, Illinois Institute of Technology; May 19, 1944.

"Report on Illinois Professional Engineering Licensing Law," by Beverly Dudley, McGraw-Hill Publishing Company; May 19, 1944.

Election of Officers; May 19, 1944.

CINCINNATI

"Development of the SCR284 Field Radio Set," by H. V. Noble, Crosley Corporation; April 18, 1944.

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"Ultra-High-Frequency Measurements," by E. D. Cook, General Electric Company; May 12, 1944.

Election of Officers; May 12, 1944.

DALLAS-FORT WORTH

"The General Electric Magnetic-Wire Recorder," by W. R. David, General Electric Company; May 22, 1944.

DAYTON

"Frequency Modulation," by M. G. Crosby, RCA Communications; April 27, 1944.

Election of Officers; April 27, 1944.

"Wave Guides—A New Means of Transmitting Radio-Frequency Power," by G. C. Southworth, Bell Telephone Laboratories; May 25, 1944.

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"Recent Improvements in Radio-Transformer Design," by Reuben Lee, Westinghouse Electric and Manufacturing Company; April 21, 1944.

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"Electron Microscopes," by C. H. Bachman, General Electric Company; April 28, 1944.

"Ultra-High-Frequency Measurements," by E. D. Cook, General Electric Company; May 23, 1944.

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"Ladder Networks to Obtain a 90-Degree Phase Shift Over the Audio Band of Frequency," by L. Boulet, Laval University; March 8, 1944.

"Impedance Determination through Standing-Wave Measurements," by E. W. Legris; March 8, 1944.

"The Training of Electrical Engineers," by E. A. Guillemin, Massachusetts Institute of Technology; March 22, 1944.

"The Basic Principles of Ultrasonics," by R. W. Boyle, National Research Council; April 12, 1944.

Election of Officers; April 12, 1944.

"Cathode-Ray Oscillography," by P. S. Christaldi, Allen B. DuMont Laboratories; May 10, 1944.

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"Study of Ultra-High-Frequency Tubes by Dimensional Analysis," by G. J. Lehmann and A. R. Vallarino, Federal Telephone and Radio Laboratories; May 3, 1944.

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O'Bryan, H., 3297 Worthington St., N.W., Washington, D. C.
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Tyrrell, W. A., Box 107, Red Bank, N. J.
Van Horn, R. H., Bell Telephone Laboratories, 463 West St., New York, N. Y.

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Palmquist, J. F., 3807 Somerset Dr., Los Angeles, Calif.
Ware, P., 8 Glenside Ter., Upper Montclair, N. J.

**The following admissions and transfers were approved by the Board of Directors on June 7, 1944.**

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Rideout, V. C., 190 Bergen Pl., Red Bank, N. J.
Schramm, F. B., 5 Mulberry Ave., Garden City, L. I., N. Y.
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Freeman, W. C., Jr., Sylvania Electric Products, Inc., Williamsport, Pa.
Johnson, E. M., 2638 S. Troy St., Arlington, Va.

*(Continued on page 39A)*

# Membership

*(Continued from page 38A)*

Johnson, W. D., Box 13, Station C, 150 Christopher St., New York, N. Y.
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Mueller, W. P., West Creek R.F.D. 2, Emporium, Pa.
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Schilling, M. O., Sylvania Electric Products, Inc., Williamsport, Pa.
Sherman, H., 6323 Morton St., Philadelphia, Pa.
Smithgall, H. E., Jr., Sylvania Electric Products Inc., Williamsport, Pa.
Warren, W. H., 31 Stephen St., Montclair, N. J.

### Admission to Senior Member

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### Transfer to Senior Member

Galber, R. T., 1019 N. Saint Clair St., Pittsburgh, Pa.
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Schantz, J. D., Farnsworth Television and Radio Corp., Fort Wayne, Ind.
Thompson, L. E., 606 W. Maple Ave., Merchantville, N. J.
Webb, W. L., Bendix Radio Division, Baltimore, Md.

**The following admissions to Associate grade were approved by the Board of Directors on June 6, 1944.**

Alvarez, E., Rodriouez Pena 372, Banfield, P.C. Sud.
Anderson, B. C., Box 1054, Renton Highlands, Renton, Wash.
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Badger, G. R., 1302 Crofton Rd., Baltimore, Md.
Balter, I., General Delivery, Dayton, I, Ohio
Barlow, W. A., 304 Hillside Ave., Nutley, N. J.
Beeson, W. E., 417 Main St., Glen Ellyn, Ill.
Berlin, A. D., c/o Fleet Mail Office, Halifax, N. S.
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Church, P. K., Sharon, Mass.
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Cornfeld, N. J., 3577 Valiant St., San Diego, 10, Calif.
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Dybdal, M. B., 17 Maple Dr., Dayton, Ohio
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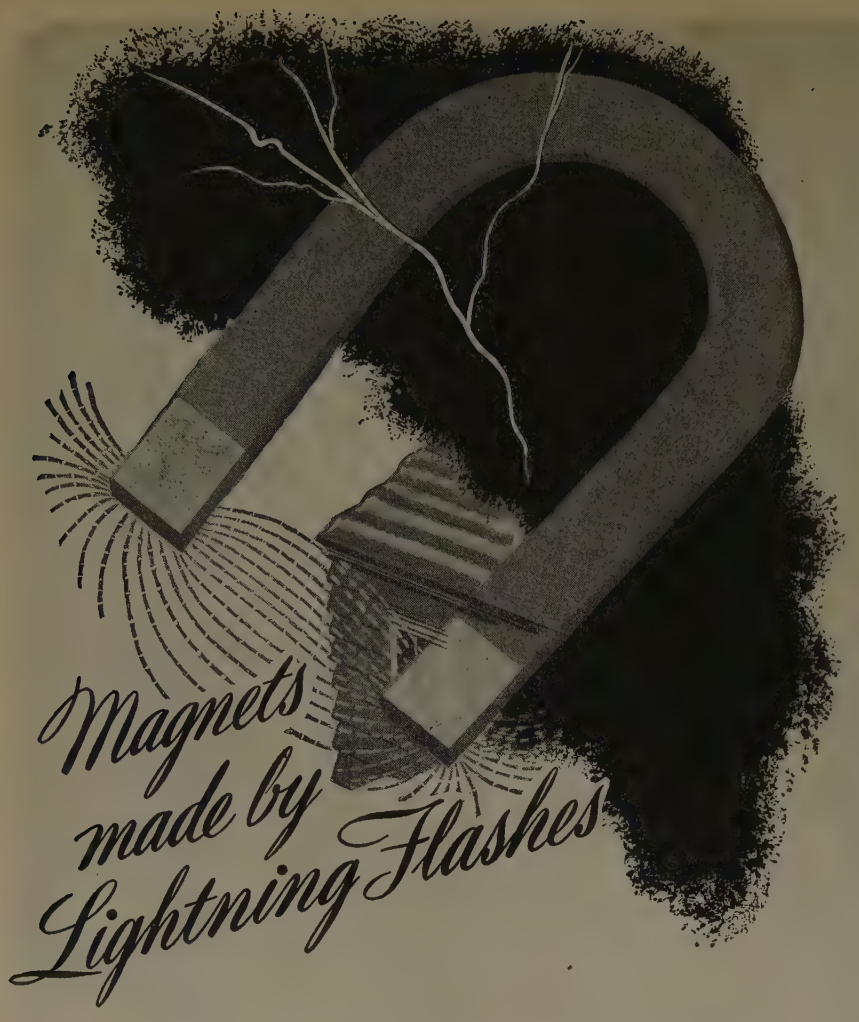


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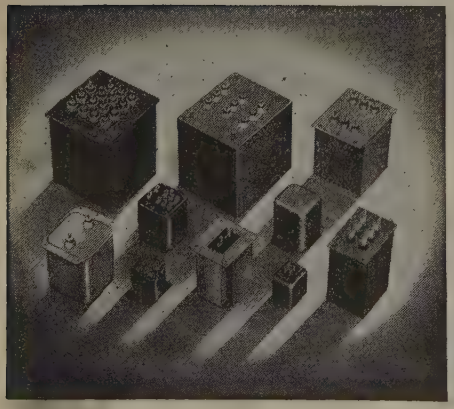

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Gunning, E. A., 413 E. Main St., Lock Haven, Pa.
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Hagstrum, W. R., R.F.D. 2, Box 611-F, Dayton, Ohio
Hallaway, A. B., 2235 Emerson Ave., Dayton, Ohio
Hamilton, K. E., Box 356, Oceanport, N. J.
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Herman, C. E., Mill Hall, Pa.
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Howeisen, H. T., 1203 Selden, El Paso, Texas
Hudson, J. W., 39 W. Wesley Rd., Atlanta, Ga.
Hughes, H. M., 4236 S. Olive St., Los Angeles, 38, Calif.
Hurlburt, E. H., 2216 R St., N.E., Washington, D. C.
Jameson, R. D., 21 Allen St., Dayton, Ohio
Jenkins, H. C., 370 Central Ave., Apt. J-1, Orange, N. J.
Jones, W. M., 4 Lombardy Pl., Towson, 4, Md.
Jones, W. G., 114 W. Susquehanna Ave., Towson, Md.
Kaarlela, A. W., R.F.D. 1, Box 199, Crystal Falls, Mich.
Kane, J. P., 5699 Goodman St., Chicago, Ill.
Kauhl, C. J., R.F.D. 5, Springfield, Ohio
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Kern, J. I., 368 Central Park Ave., Dayton, Ohio
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Lobo, G., I.E.M.E. Officer's Mess, Quetta, British India
Long, F. A., 46-41 Forest Dr., Douglaston, L. I., N. Y.
McVea, N. C., 68B Galyan Dr., West Park, Bremerton, Wash.
Maloy, E. S., Jr., 123 N. Thomas St., Bellefonte, Pa.
Manhart, R. C., Sylvania Electric Products, Inc., Emporium, Pa.
Marconi, A., Pampa 3896, Buenos Aires, Argentina
Martinez, V. M., Circuito CMQ, S.A., Montey Prado, Habana, Cuba

*(Continued on page 42A)*

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Whether it is a military mission or a scheduled flight of a commercial air liner...there can be no failures in radio communications. Now, both military and commercial aircraft all over the world communicate via Wilcox. For many years Wilcox dependability has been proved under all operating conditions.

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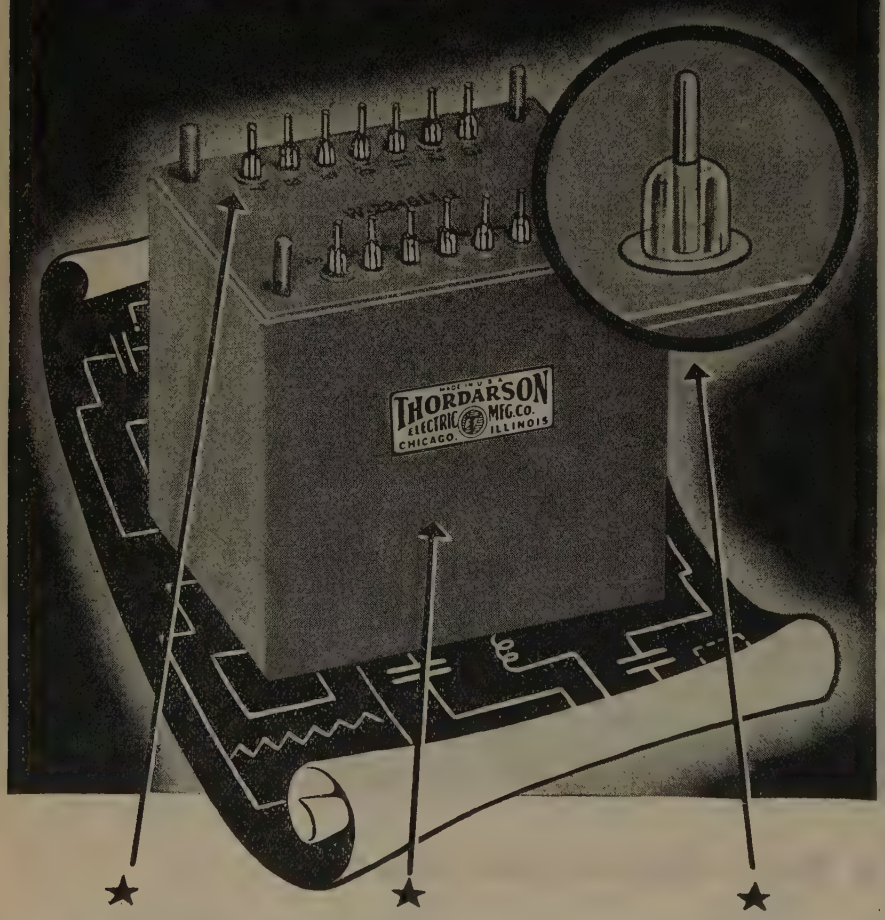


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High efficiency in a small package...this compact high frequency power transformer (60 to 2600 c. p. s.) fills a difficult airborne application.

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Mason, C. F., Radio Material Office, Eleventh Naval Dist., San Diego, 30, Calif.
Merkle, E. C., 1959 Gondert Ave., Dayton, Ohio
Moriarly, O. M., c/o Navy Office, Melbourne, Australia
Moran, R. B., Jr., 3328 Martha Cir., Pasadena, Calif.
Mutch, J. J., 2500 E. Strathmore Ave., Baltimore, Md.
Myers, C. J., 143 Linden Blvd., Brooklyn, N. Y.
Nadel, A., School of Electrical Engineering, Purdue University, Lafayette, Ind.
Neuenschwander, E. F., 254 C Humble Bldg., Houston, Texas
Nichols, G. P., Jr., 543 Clinton Ave., Bridgeport, 3, Conn.
Numan, L. J., 943 M. Espenson Bldg., Houston, Texas
Odien, E. J., 1567 Kensington Ave., Buffalo, N. Y.
Oster, R. E., 204 S.E. 18 Ct., Ft. Lauderdale, Fla.
Palmer, C. R., 414 Alliance Pl., Dayton, Ohio
Parsons, E. M., Box J, Nantasket Beach, Mass.
Parker, J. W., 34 Cranham Rd., Romford, Essex, England
Pepiot, L. S., 405 E. Ward St., Versailles, Ohio
Pfund, C. E., 133 Hickory St., Bridgeport, Conn.
Pockman, L. T., 3321 Anza St., San Francisco, Calif.
Pray, E. B., Box 1021, Lawrence, Mass.
Prentiss, R. A., NDRC, 50 floor, 350 Fifth Ave., New York, 1, N. Y.
Price, H. W., Jr., 521 Anthony St., Baltimore, Md.
Rafael, R., Box 334, Angola, Ind.
Resetich, A. J., 4406 N. Mozart Ave., Chicago, Ill.
Richardt, R. W., 125 Third St., Wausau, Wis.
Rinn, F. H., 400 S. High St., Lock Haven, Pa.
Riesmeyer, A. H., 5 Kenwood Lane, Collinsville, Ill.
Rommel, T. A., 3570 S. Tacoma Ave., Tacoma, Wash.
Rotker, W., Temco, Engineering Department, 345 Hudson St., New York, N. Y.
Sanborn, B. M., 3320 N. Dixie Dr., Dayton, Ohio
Sanford, H. N., 1204 E. Colonial Dr., Apt. 2, Orlando, Fla.
Schantz, G. W., 1654 Huffman Ave., Dayton, Ohio
Schlingloff, G. F., Fourth and Beach Ave., Beach Haven, N. J.
Scholer, R. E., 261 Washburn Ave., N., Minneapolis, Minn.
Sckell, A., Paroissien 3960, Buenos Aires, Argentina
Sellers, P. T., 1612 Milam St., Houston, Texas
Shongut, R., 210 W. 90 St., New York, N. Y.
Shellhaas, R. D., R.F.D. 1, West Milton, Ohio
Siemianowski, E. J., Co. E., 847 Sig. Tng. Bn., Camp Crowder, Mo.
Singer, H. J., 419 Concord Ave., N.W., Washington, D. C.
Smith, L. L., 122 E. Water St., Lock Haven, Pa.
Sproule, R. A., 23 Colinton Maines Pl., Edinburgh, 13, Scotland
Stengel, E. S., 119½ E. Water St., Lock Haven, Pa.
Stevens, A. W., Bureau Ships 903, Navy Dept., Washington, D. C.
Stiles, A. C., Jr., 2915 Wheeling St., El Paso, Texas
Strain, C. E., 1289 Niles Ave., N.W., Atlanta, Ga.
Stryker, W. G., Box 587A, R.F.D. 9, Dayton, Ohio
Sullivan, F. L., 1417 S. University, Denver, 10, Colo.
Svancara, V. J., 1228 Epworth Ave., Dayton, Ohio
Sydell, J. H., 144 O'Fallon St., Bellevue, Ky.
Tewell, R. H., 1311 Lincoln Ave., Bremerton, Wash.
Thurston, J.N., 173 Hancock St., Cambridge, Mass.
Tompos, S. S., 9551 Mark Twain Ave., Detroit, 27, Mich.
Toole, L. J., c/o General Cable Research Laboratory, Avenue A and First St., Bayonne, N. J.
Travis, E., 93 Broad St., San Luis Obispo, Calif.
Turconi, R. S., 5 S. Jared St., Du Bois, Pa.
Tuxill, A. R., 3131 Strawberry La., Port Huron, Mich.
Tvedt, T. J., 1902 McDuffie, Houston, Texas
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*(Continued on page 46A)*

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In d.c. machines, such as Eicor motors and dynamotors, commutation reverses current direction thousands of times per second, each reversal involving the making and breaking of a momentary contact. To provide years of unfailing service, the commutators must be large enough to carry the current and dissipate the heat but still be of a diameter small enough to afford moderate peripheral speed and long brush life. Division of the commutator into segments of proper number is based on such factors as voltage, composition and size of brushes, and on performance requirements.

The individually formed copper and mica segments are hydraulically swaged into permanent position on the mica lined steel core. After heat treating, high potential tests are made between segments and from each segment to ground to prove insulation. When the commutator is mounted and connected as part of a complete armature, it is finished by turning and undercutting (illustrated), and then by machining to concentric limits measured in "tenths."

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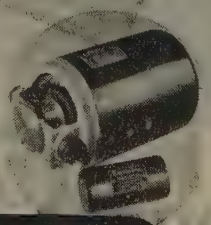

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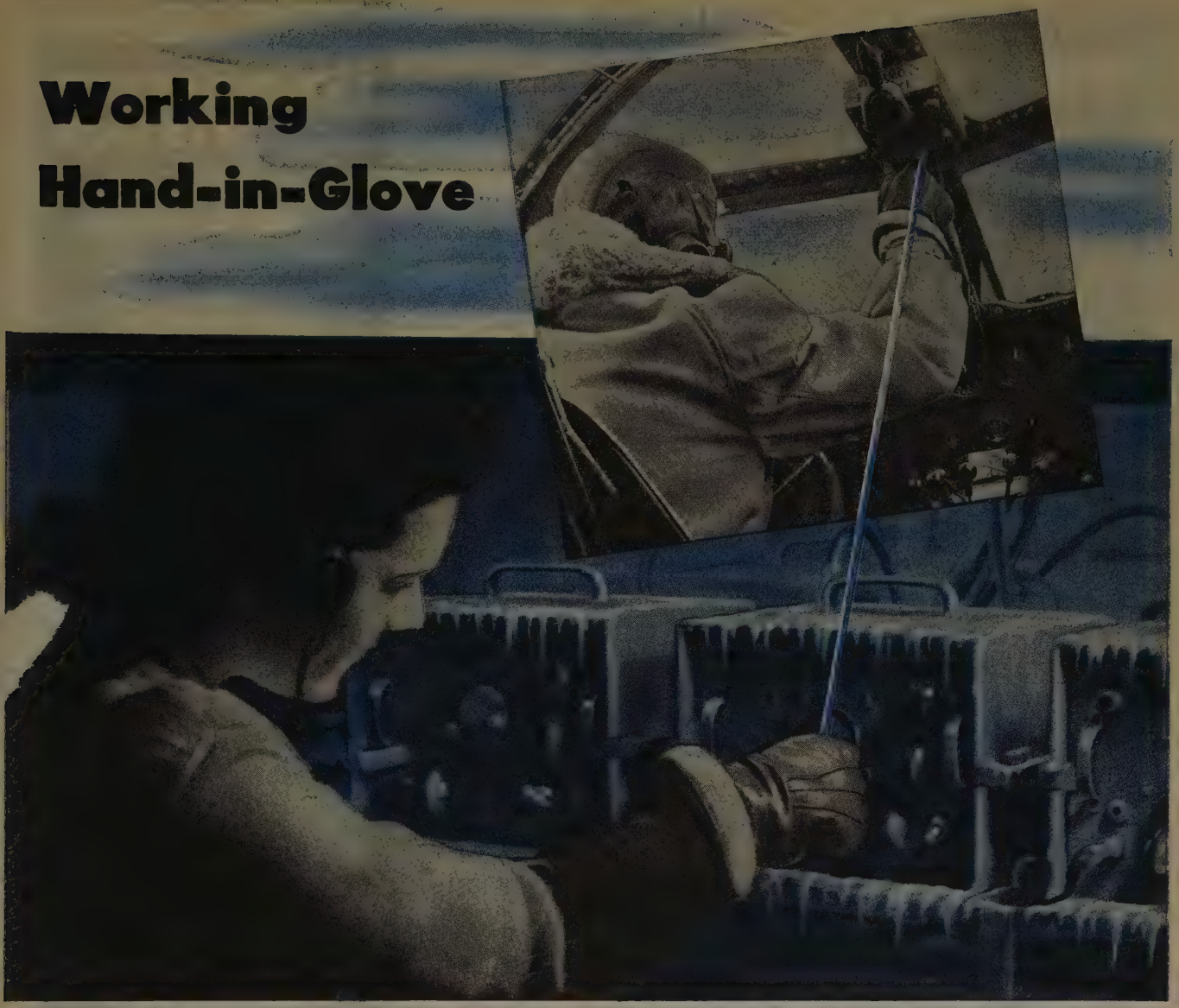
Venn, D. A., 1801—25 St., S.E., Washington, 20, D. C.
Verbance, A., 358 S. Terrace Ave., Columbus, 4, Ohio
Wahle, J. J., Section H, Boca Raton Club, Boca Raton, Fla.
Wakelee, C. L., 2427 Harvard North, Seattle, 2, Wash.
Walker, P. E., 7716 Scout Ave., Bell Gardens, Calif.
Walker, P. H., British Broadcasting Corp., Droitwich, Worcestershire, England
Walsh, W. C., 34 Grattan St., San Francisco, Calif.
Waterman, L. W., 1501 E. Hampden Ave., Englewood, Ohio
Wehrman, H. F., KLZ, Denver, 2, Colo.
Weiler, P. R., 6338 S. Lorel Ave., Chicago, Ill.
Weiss, L., 129 Rock Creek Rd., New Haven, Conn
Welker, J. J., 29 North St., Madison, Wis.
Westneat, A. S., Jr., Box 271, Columbia University, New London, Conn.
Whaley, S., 1822 S. Mount Olive, Siloam Springs, Ark.
Wheatley, B. M., YMCA Hostel, Wormley, Godalming, Surrey, England
White, A. S., Jr., 95 E. Front St., Red Bank, N. J.
White, E. S., Chicago Signal Corp., Inspection Zone 1, N. LaSalle St., Chicago, Ill.
Woodruff, C. M., 101 Lewiston Rd., Dayton, Ohio
Wynne, E. O., 3816 Windom Pl., N.W., Washington, D. C.
Young, W. R., 332 A St., Sheridan Parkside, Tonawanda, N. Y.
Zarpaylic, J., 118 Glover Ave., Paterson, N. J.
Zick, E. J., 937 Wisconsin Ave., St. Joseph, Mich.

**The following Students were transferred to the Associate grade during January, February, March, and April, 1944.**

Adler, Bernard, Quincy, Mass.
Aiken, Elmer W., Dayton, 4, Ohio
Albrecht, Albert, Los Angeles, Calif.
Alcantara, Rogelio R., Buenos Aires, Argentina
Alexander, Frank C., Jr., Pittsburgh, Pa.
Allured, Jonathan B., Northampton, Mass.
Amrhein, Oscar C., St. Louis, 9, Mo.
Anderson, John G., Dante, Va.
Anderson, Robert I., Garden City, L. I., N. Y.
Angelo, E. J., Jr., New Orleans, La.
Apolenis, Charles J., Allentown, Pa.
Ashbrook, Fred M., Cambridge, Mass.
Asmuth, John L., Boston, 15, Mass.
Atkinson, James R., Washington, D. C.
Austin, William R., Philadelphia, Pa.
Avis, Alexander J. A., Palo Alto, Calif.
Bailey, B. L., San Francisco, Calif.
Balashek, Stephen, Newark, 6, N. J.
Bamford, Donald, Toronto, 13, Ont., Canada
Bangert, John T., New York, 14, N. Y.
Barron, Bert, Los Angeles, Calif.
Barton, Charles A., New York, 21, N. Y.
Bauersfeld, Charles F., Richmond Hill, L. I., N. Y.
Beitz, Ruben E., Schenectady, N. Y.
Benjamin, J. Malvern, Jr., Baltimore, Md.
Bennett, Robert, Montreal West, Que., Canada
Benware, R. T., Philadelphia, Pa.
Berger, Fred, Middletown, N. Y.
Berry Charles D., Ridgewood, N. J.
Bjerke, John W., Twin Valley, Minn.
Bey, Paul P., New York, N. Y.
Blacker, Harry L., Winnipeg, Man., Canada
Black, John C., Vashon, Wash.
Boege, Frederick G., Red Bank, N. J.
Bonadies, Vincent J., Philadelphia, Pa.
Bowman, David F., Little Neck, L. I., N. Y.
Bowman, Jesse Y., San Francisco, Calif.
Boyer, John L., Wilkinsburg, Pa.
Bradford, Charles E., Brooklyn, N. Y.
Brenner, G. J., Jr., Saginaw, Mich.
Brettell, George A., Jr., Newark, 4, N. J.
Brewer, Alexander F., Garden City, L. I., N. Y.
Brittain, Gilbert H., Bronx, N. Y.
Brodzinsky, Albert, Washington, D. C.
Brooks, F. E., Jr., Austin, 21, Texas

*(Continued on page 58A)*

# Working Hand-in-Glove



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"CALLING D FOR DORIS . . . CALLING D FOR DORIS . . ." Somewhere up in the stratosphere, a flier's gloved hand flicks on a Bendix* Aircraft Radio and the voice of the squadron leader comes in clear and crisp, unblurred by the biting cold. The operating frequency is correct . . . set by means of a frequency standard which a girl's gloved hand tested here in the Bendix "cold box," where 40-below temperatures duplicate conditions of altitude flying.

Bendix Radio employees thus literally work hand-in-glove with our fliers . . . testing aircraft radio equipment for its ability to function not only in the bleak cold of the upper air, but in the blistering heat of the tropics . . . in desert dryness and jungle humidity . . . for its ability to stand up under combat strains and landing shock. Bendix engineers have devised more than a thousand such tests and inspections covering every stage of production, from single parts and sub-assemblies to the compact, finished radio.

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*(Continued from page 46A)*

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Brown, H. Walcott, Jr., Haddonfield, N. J.
Brown, Jacob S., Baltimore, Md.
Bullock, John B., Cambridge, Mass.
Bunger, John W., Scotia, N. Y.
Burkart, Joseph A., Riverdale, N. Y.
Burke, James T., Oak Hill, W. Va.
Burns, Leslie L., Jr., New York, 25, N. Y.
Busse, C. Clark, Pittsburgh, 5, Pa.
Cann, Arthur F., Danvers, Mass.
Carlson, Arthur F., Miami, Fla.
Cater, John R., Baltimore, 1, Md.
Caywood, Thomas E., Cambridge, 38, Mass.
Caywood, William P., Jr., Pittsburgh, Pa.
Chitty, H. W., Washington, D. C.
Chase, David G., Washington, 10, D. C.
Church, Raymond L., Sioux City, Iowa
Clapp, Fred D., Santa Cruz, Calif.
Clapp, Roger E., Cambridge, Mass.
Clark, Gordon L., San Francisco, Calif.
Clark, John J., Jr., Washington, 20, D. C.
Cline, Dudley E., Brooklyn, N. Y.
Cohn, Daniel E., Los Angeles, Calif.
Cohn, Seymour B., Cambridge, Mass.
Cole, Walter A., Winnipeg, Manit., Canada
Colehower, C. Harris, Jr., Merion, Pa.
Colloff, Isadore, Asbury Park, N. J.
Conklin, E. Biddle, Jr., Ironton, Ohio
Conte, Theodore M., Richmond, Va.
Conway, John, Pittsburgh, 6, Pa.
Cooper, Ronald G., Wilstead, Beds., England
Corse, William F., New Freedom, Pa.
Corl, John L., Emporium, Pa.
Costa, John J., Bronx, N. Y.
Couch, Charles R., Jr., Gainesville, Fla.
Cox, John W., North Arlington, N. J.
Crothers, M. H., Brookings, S. D.
Cuccia, C. Louis, Princeton, N. J.
Daskam, Edward, Schenectady, N. Y.
Dau, Walter K., Jr., Arlington, Va.
Dayot, Vivencio D., West Palm Beach, Fla.
Deakins, Glenn, Cambridge, Mass.
De Mers, Edwards F., Rochester, 3, N. Y.
Dewey, Gordon C., New York, N. Y.
Dinsmore, Edmund G., Boston, Mass.
Dishington, Roland H., Hollywood, Calif.
Dennison, B. H., Jr., Alexandria, Va.
Dlouhy, Frank W., Newark, 5, N. J.
Dobson, William T., Garden City, L. I., N. Y.
Drazy, Elbert J., East Orange, N. J.
Dolberg, Charles E., Germantown, Pa.
Dowell, Arthur E., Washington, 16, D. C.
Duncan, Hugh S., Flushing, L. I., N. Y.
Eber, M., East Orange, N. J.
Echtman, Lionel, New York, N. Y.
Edutis, V. L., Washington, D. C.
Edwards, Russell N., New Haven, Conn.
Elias, Louis G., Danbury, Conn.
Ellis, Bernard T., Jr., Summit, N. J.
Engel, James S., Newark, 1, N. J.
Epstein, David J., New York, N. Y.
Falk, Alfred E., Fort Wayne, Ind.
Farnsworth, Neil B., Hempstead, L. I., N. Y.
Fathauer, George H., Indianapolis, Ind.
Fernald, O. H., Upper Montclair, N. J.
Ferrante, Frank M., New York, N. Y.
Fisher, George W., Toronto, Ont., Canada
Flock, Warren L., Cambridge, Mass.
Frederick, Arden H., Cambridge, Mass.
Freed, Philip J., East Orange, N. J.
Friedl, E. Mack, Bridgeport, Conn.
Frontjes, Melbourne, Flint, Mich.
Fulmer, John R., Jr., Clearfield, Pa.
Fulmer, Norman C., East Orange, N. J.
Fulton, James A., Jr., Mobile, Ala.
Gaba, Herbert, Lincoln, Neb.
Gamble, Joseph H., Hempstead, L. I., N. Y.
Garber, Sumner H., Boston, Mass.
Ghelardi, Raymond P., Cambridge, 39, Mass.
Godbey, Joe J., Washington, D. C.
Gordon, Daniel I., Silver Spring, Md.
Grantham, R. E., Washington, 20, D. C.
Greenleaf, Francis D., Foxboro, Mass.
Gregory, Arthur H., Montreal, Que., Canada
Guarrera, John J., Cambridge, Mass.

*The names of Students transferred to the Associate Grade for the letters H through Z will be published in the next issue.*

ENGINEERING EXPERIENCE and Manufacturing Facilities for

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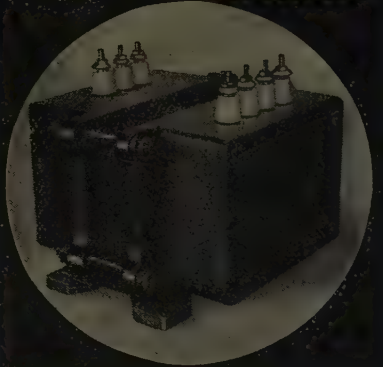

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# NO SUBSTITUTE NEEDED!

## USE HYTRON 6AL5 VERY-HIGH-FREQUENCY TWIN DIODE

TYPE 6AL5
(Developmental Hytron D27)

BASING
Pin 1 — Cathode 1
Pin 2 — Plate 2
Pin 3 — Heater
Pin 4 — Heater
Pin 5 — Cathode 2
Pin 6 — Shield
Pin 7 — Plate 1

CONSTRUCTIONAL FEATURES

1. Rugged mount is supported by short, heavy stem leads as well as by top mica.
2. Close cathode-to-plate spacing gives high perveance. (Note close coating [illegible])
3. Electrostatic shield connects to pin 6.
4. Baffle mica shields the elements from getter spray.
5. Miniature stem permits negligible lead inductance and minimum interelectrode capacitances.

The 6AL5 fills the need for a high perveance twin diode with the low voltage drop required for many special r.f. circuit applications. WPB and the Services consider diode connection of the 6J6 twin triode (and other triodes) to be a wasteful misuse. With minor changes of socket wiring, the 6AL5 easily replaces the diode-connected 6J6.

Specifically manufactured and rated as a diode, the 6AL5 is tested as a diode. Close production control keeps within a narrow range the cutoff characteristic in the contact potential region. Designed throughout for efficiency on high and very-high radio frequencies, the 6AL5 has a separately connected shield which may be grounded to isolate the two diodes and their associated circuits. A midget miniature bulb permits extra space savings.

Possible uses include: Detector and AVC, clipper, limiter, FM frequency discriminator, special high-frequency diode, power rectifier.

### HYTRON TYPE 6AL5
**Very-High-Frequency Twin Diode**

**ELECTRICAL CHARACTERISTICS**

| | |
|---|---|
| Heater potential (AC or DC) | 6.3 volts |
| Heater current | 0.3 amperes |
| Peak inverse potential† | 460 max. volts |
| Heater-cathode potential† | 350 max. volts |
| Peak plate current per plate† | 60 max. ma. |
| Average plate current per plate† | 10 max. DC ma. |

**INTERELECTRODE CAPACITANCES**

| | |
|---|---|
| Plate 1 to plate 2 | 0.015 mmf. |
| Plate to cathode* | 2.8 mmf. |
| Cathode to all* | 3.8 mmf. |

Capacitances are averages with close-fitting shield.

**PHYSICAL CHARACTERISTICS**

| | |
|---|---|
| Bulb | T-5½ midget |
| Base | Miniature button 7-pin |
| Height overall | 1.82 inches max. |
| Diameter | 0.75 inch max. |

† Maximum ratings shown are absolute; design maximums should be approximately 10% lower to allow for line voltage variations.
* Value is for one of the two twin diode sections.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

**HYTRON CORPORATION** ELECTRONIC AND RADIO TUBES

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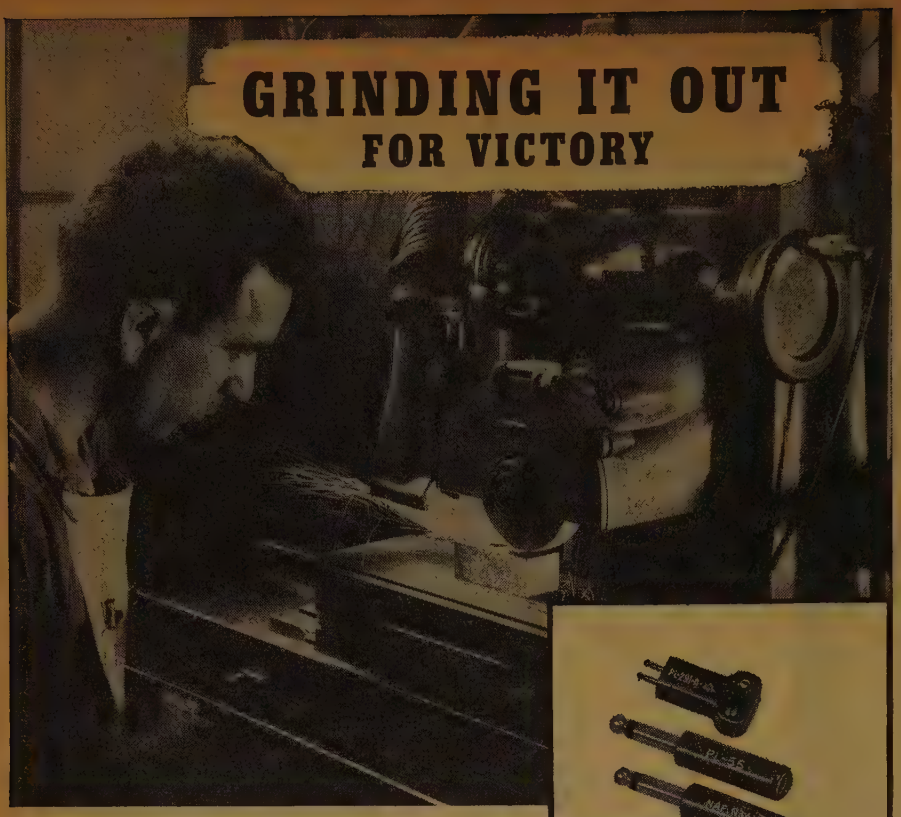

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## PLUGS & CONNECTORS

### Signal Corps and Navy Specifications

| Types: | | PL | | |
|---|---|---|---|---|
| 50-A | 61 | 74 | 114 | 150 |
| 54 | 62 | 76 | 119 | 159 |
| 55 | 63 | 77 | 120 | 160 |
| 56 | 64 | 104 | 124 | 291-A |
| 58 | 65 | 108 | 125 | 354 |
| 59 | 67 | 109 | 127 | |
| 60 | 68 | 112 | 149 | |

| PLP | | PLQ | | PLS | |
|---|---|---|---|---|---|
| 56 | 65 | 56 | 65 | 56 | 64 |
| 59 | 67 | 59 | 67 | 59 | 65 |
| 60 | 74 | 60 | 74 | 60 | 74 |
| 61 | 76 | 61 | 76 | 61 | 76 |
| 62 | 77 | 62 | 77 | 62 | 77 |
| 63 | 104 | 63 | 104 | 63 | 104 |
| 64 | | 64 | | | |

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## SECTION MEETINGS

BALTIMORE

"Recent Experiences with United States Military Equipment in the South Pacific Combat Zone," by E. A. Post, Aircraft Radio Laboratories; May 23, 1944.

BUFFALO-NIAGARA

"The Uses and Applications of the Cathode-Ray Oscilloscope," by F. A. Lidbury, Oldbury Electro-Chemical Company; May 18, 1944.

Election of Officers; May 18, 1944.

DALLAS-FORT WORTH

"Tone Channeling," by Ralph Rea, Civil Aeronautics Authority; June 15, 1944.

DETROIT

"Comparison of Amplitude Modulation and Frequency Modulation As Applied to Police Radio Systems," by Edwin Denstaedt; Detroit Police Radio; May 19, 1944.

"The Radio Engineer Cannot Become A Solifidian," by Beverly Dudley, *Electronics:* June 16, 1944.

EMPORIUM

"The Klystron," by D. R. Hamilton, Sperry Gyroscope Company; June 6, 1944.

NEW YORK

The First Joint Radio Old Timers Meeting, G. H. Clark, Master of Ceremonies; June 7, 1944.

PITTSBURGH

Business Meeting; June 12, 1944.

Election of Officers; June 12, 1944.

PORTLAND

"Broadcast Antenna Design and Adjustment Considerations," by Wilson Pritchett, Oregon State College; June 9, 1944.

ST. LOUIS

"Frequency Modulation," by M. W. Woodward, Commercial Radio Equipment Company; May 25, 1944.

Election of Officers, May 25, 1944.

TWIN CITIES

"Precision Measurements and Production Today by Duall," by R. O. Wredberg, Duall Twin Cities Company; May 23, 1944.

WASHINGTON

"Postwar Electronics," by F. H. McIntosh, Consulting Radio Engineer; June 12, 1944.

WILLIAMSPORT

"The Handling of Telegrams by Facsimile," by I. S. Coggeshall, Western Union Telegraph Company; May 5, 1944.

"Electronic Voltage Regulators," by L. I. Knudson, Sylvania Electric Products, Inc.; June 9, 1944.

## MEMBERSHIP

**The following admissions and transfers were approved on July 5, 1944.**

### Admission to Member

Backer, C. M., Biltmore Hotel, Dayton 2, Ohio

Bennett, H. W., 143 Rockland Rd., Bridgeport, Conn.

Bowyer, V. T., B.A.C., 1520 New Hampshire Ave., Washington, D. C.

Brett, H. M., 166 Mountain Way, Rutherford, N. J.

*(Continued on page 37A)*

# Membership

*(Continued from page 34A)*

Jensen, A. K., 5511 Homeside Ave., Los Angeles, Calif.
Kintzel, J. D., c/o A. C. Nielsen Co., 2101 W. Howard St., Chicago, Ill.
Knight, A. R., 1657 Hearthstone Dr., Dayton, 10, Ohio
Rhein, G. W., Mackay Radio and Telegraph Co., 67 Broad St., New York, 4, N. Y.
Rudensey, M. B., 15 Walter Pl., Irvington, N. J.
Sandberg, D. A., 872 Clifton Crest Ter., Cincinnati, Ohio
Schutz, H., 54 Lyme Rd., Hanover, N. H.
Stafford, J. W., Apt. 315, 26 Concord Ave., Cambridge, 39, Mass.
Wright, C. M., 19 Glen Ave., Ottawa, Ont., Canada
Zink, A. J., Jr., 64 Whitlier St., Andover, Mass.

## Transfer to Member

Browder, J. E., 365 Stewart Ave., Garden City, L. I., N. Y.
Cafferata, H., Knotty Ash, Greenways, Broomfield Rd., Chelmsford, Essex, England
Choat, W. F., 38 Grenview Blvd., Toronto, Ont., Canada
Eubank, R. N., 1227 Windsor Ave., Richmond 22, Va.
Fleming, C. C., 173-08—82 Ave., Jamaica, L. I. N. Y.
Giacoletto, L. J., Eatontown Signal Laboratory, Ft. Monmouth, N. J.
Goodell, E. M., 224 E. Third St., Emporium, Pa.
Greene, F. M., Apt. 3, 5311—38 Ave., Hyattsville, Md.
Haynes, N. M., 1115B., Ninth St., Far Rockaway, L. I., N. Y.
Hoisington, D. B., 48-02 Browvale La., Little Neck, L. I., N. Y.
Hopkinson, T. W., 600 Bashford La., Alexandria, Va.
LaPierre, V. M., Pan American-Grace Airways, Inc., Lima, Peru
McKnight, G. P., 325 Charles St., St. Marys', Pa.
Nye, J. H., 4035 Ithaca St., Elmhurst, L. I., N. Y
Petts, R. G., 1004 Cherry St., Williamsport, Pa.
Priebe, F. K., 40 Woodland Dr., Fair Haven, N. J.
Reash, C. W., Box 11, Emporium, Pa.
Seidner, J. H., 516 E. Alleghany Ave., Box 401, Emporium, Pa.
Shultise, Q. M., 64 Avenue of Two Rivers, Rumson, N. J.
Siemens, R. H., c/o RCA Argentina, Paroissien 3906 Buenos Aires, Argentina
Summerford, D. C., 3037 Wirth Ave., Louisville 4, Ky.
Swan, E. O., CKRL, 444 University Ave., Toronto, Ont., Canada
Swendson, L. G., 30 Miller Ave., Fairfield, Ohio
Talpey, R. G., Stromberg-Carlson Company, Rochester, N. Y.
Van Niman, R. T., c/o Motiograph, 4431 W. Lake St., Chicago, Ill.
Wainwright, R. M., Rm. 3D320, Pentagon-OCSigO, Washington, 25, D. C.
White, S. D., Bell Telephone Laboratories, 463 West St., New York, N. Y.

## Admission to Senior Member

Barrett, A. E., Rm. 506 Grafton Hotel, 1139 Connecticut Ave., N. W., Washington 6, D. C.
Benning, H. H., Bell Telephone Laboratories, 463 West St., New York, N. Y.
Dearle, R. C., University of Western Ontario, London, Canada
deBivar, A. M. B., Rua Rodrigo da Fonseca, 135-4 Lisbon, Portugal
Morrical, K. C., Underwater Sound Laboratory, Harvard University, Cambridge, Mass.

## Transfer to Senior Member

Akerman, B., 2646 Cheshire Bridge Rd., N. E., Atlanta, Ga.
Avery, R. D., 27 Violet Ave., Mineola, L. I., N. Y.
Bauer, B. B., 1179 S. Harvey Ave., Oak Park, Ill.
Callanan, J. A., 6825 N. Olcott Ave., Chicago, Ill.

*(Continued on page 38A)*


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Collison, P. B., Underwater Sound Laboratory, Ft. Trumbull, New London, Conn.
Corderman, R. C., 45 Clinton Ave., Maplewood, N. J.
Cotter, W. F., Stromberg-Carlson Company, Rochester, N. Y.
Curtiss, A. N., 5521 N. Pennsylvania St., Indianapolis, 5, Ind.
Frankel, S., 72–38—113 St., Forest Hills, L. I., N. Y.
Gessford, R. K., Sylvania Electric Products, Inc., Emporium, Pa.
Heiser, E. S., 208 Uptown Post Office, St. Paul, Minn.
Hendricks, L. A., Aircraft Radio Laboratory, Wright Field, Dayton, Ohio
Huxtable, C. K., 736 Michigan Ave., Evanston, Ill.
Kaufman, J., Box 406, Ross, Calif.
Luttgens, H. C., c/o National Broadcasting Company, Merchandise Mart, 222 N. Bank Dr., Chicago, 54, Ill.
McNally, J. O., Bell Telephone Laboratories, 463 West St., New York, N. Y.
Miles, P. D., 707 Berry St., Falls Church, Va.
Mossman, F. B., 3822—43 Ave., N. E., Seattle 5, Wash.
Pounsett, F. H. R., 23 Parkhurst Blvd., Leaside, Ont., Canada
Serrell, R., 786 Palmer Rd., Bronxville, N. Y.
Sussman, H., 1909 Hollingshead Ave., Pennsauken, N. J.
Wagener, W. G., c/o Heinz and Kaufman, Ltd. South San Francisco, Calif.
Williams, E. M., Research Division, Aircraft Radio Laboratory, Wright Field, Dayton, Ohio
Woonton, G. A., 714½ Maitland St., London, Ont., Canada

**The following admissions to Associate grade were approved on July 5, 1944.**

Apple, H. L., Box 173, College Park, Md.
Artkin, W. H., Jr., 101 Armstrong Ave., Toronto, Ont., Canada
Ayton, J., 314 W. Fifth St., Emporium, Pa.
Bacher, G. L., c/o Fleet P. O. San Francisco, Calif.
Baird, J. W., Highway Patrol Radio WANL, Elizabethtown, N. C.
Bard, L. T., 5512 Park Heights Ave., Baltimore 15, Md.
Barron, F. E., 1108 E. Broad, Montoursville, Pa.
Barto, D. L., 375 Union Ave., Williamsport, Pa.
Beckstead, D. L., 1685 Sunset Cliff Blvd., San Diego 7, Calif.
Behr, J., 118–44—223 St., St. Albans 11, L. I., N. Y.
Bellinger, G. B., 1515 W. Munroe St., Chicago 7, Ill.
Berger, A. L., 78 Eighth Ave., Brooklyn 15, N. Y.
Berinsky, M., 130 W. 91 St., New York, N. Y.
Bernat, L., 5200 Blackstone Ave., Chicago, Ill.
Bernstein, C., 159 Gelston Ave., Brooklyn 9, N. Y.
Biddle, H. A., 50 E. Wister St., Germantown, Pa.
Blackmon, T. M., 3111 Midvale Ave., Los Angeles 34, Calif.
Bolenbaugh, R. K., 30 Ritchie Ave., Wyoming, Ohio
Bose, G. L., 299 Jackson St., Hempstead, L. I., N. Y.
Brown, B. B., 32 Hawthorne Ave., Princeton, N. J.
Brown, E. M., 273 N. Franklin St., Hempstead L. I., N. Y.
Brown, H. R., 3635 Heaton St., Fresno 2, Calif.
Bundy, R. F., Jr., 109 Ave. L, Newark, N. J.
Burton, B. L., 610 S. Caroline Ave., S. E., Washington, D. C.
Bussom, C. J., 600 Wyoming St., Williamsport, Pa.
Caproni, G. A., 912 North 47, Seattle 3, Wash.
Chase, M. N., 308B S. Freeman St., Inglewood, Calif.
Cheadle, J. N., 502 S. Duluth Ave., Sioux Falls, S. D.
Churchman, A., 95 Ipwich Rd., Colchester, Essex, England
Clark, J. H., 237 Heath St., Buffalo 14, N. Y.
Condon, R. J., Office of War Information, APO 887, Postmaster, New York, N. Y.

*(Continued on page 40A)*

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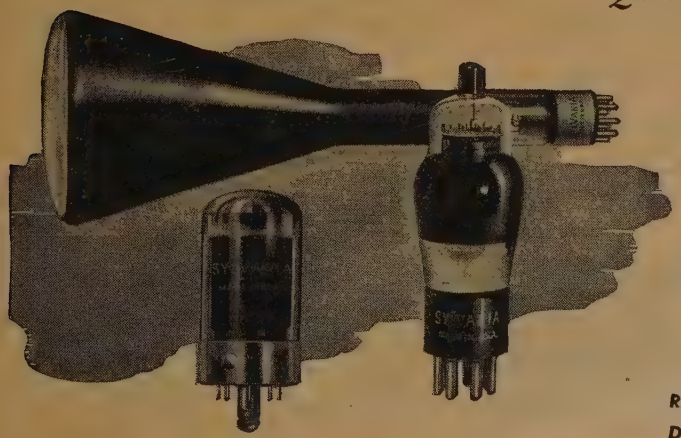

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Daly, G. M., 509 Harrison Ave., West Collingswood, N. J.
Davidson, C. F., G.P.O. Radio Laboratories, Palace of Engineering, Wembley, Middlesex, Eng.
Dorman, C. H., 4415 W. Dakota St., Seattle 6, Wash.
Downie, W. A., 1552 E. 76 St., Seattle 5, Wash.
Downs, G. L., 70 E. Vans St., Watertown, Mass.
Dowsley, R. E., 178 Glengariff Rd., Massapequa Park, L. I., N. Y.
Driggs, L. O., 3414—25 Ave. S., Minneapolis, Minn.
Dutton, I. L., 1595 Clay St., San Francisco, Calif.
Exley, G. A., 2205 Arden Rd., Baltimore 9, Md.
Fennel, D. C., 1441 Drummond St., Montreal, Que., Canada
Fort, W. G. S., Fairchild Aircraft, Burlington, N. C.
Friedman, H., 6087 Pickford Pl., Los Angeles 35, Calif.
Gallagher, C. B., 1544 Rolling Rd., Relay 27, Md.
Gilleran, J. J., 1434 Neilson St., Berkeley, Calif.
Gore, J. K., Box 189, Emporium, Pa.
Gould, N. G., 75 Winn Rd. Lee, London, S. E. 12, England
Gull, H. P., Fleet P. O., New York, N. Y.
Gunther, H. S., 355 E. 50 St., New York 22, N. Y.
Hall, C. H., 1823 Lincoln Dr., Williamsport, Pa.
Hangen, W. E., R.F.D. 1, Box 225, Dayton, Ohio
Hannah, W. M., 29 Pennington St., Paterson 3, N. J.
Hartmann, C. L., 4113 W. Cornelia Ave., Chicago 41, Ill.
Healy, L. J., 3822 Ridgecroft Rd., Baltimore 6, Md.
Heyd, J. W., 873 St. Agnes Ave., Dayton 7, Ohio
Hilderbrand, E. A., RCA Service Co., Bldg. 5–6, Camden, N. J.
Hoddinott, E. V., 102 W. Clay St., Baltimore 1, Md.
Hummel, J. F., 568 Locust St., Lancaster, Ohio
Ito, M., 36–55—36 St., Long Island City 1, L. I., N. Y.
Jones, E. J., 78 Dellwood Rd., Cheektowaga 21, N. Y.
Kantrowe, J. H., 402–5 Mutual Home Bldg., Dayton 4, Ohio
Kenigson, R. B., Lt., APO 887, New York, N. Y.
Kenney, W., Graybar Electric Co., 201 Sante Fe Ave., Los Angeles 12, Calif.
Killen, C. W., 601 Park Ave., Piqua, Ohio
Knight, J., 3 Bond St., Maroubra, N. S. W., Australia
Lee, M., 148 Lafayette Ave., Brooklyn, N. Y.
Levan, M. T., 36 Reed St., Buffalo 12, N. Y.
Levine, S., Shore Gardens—Apt. 2D, Bath Ave., Long Branch, N. J.
Levine, S., 805 St. Marks Ave., Brooklyn 13, N. Y.
Lindgren, J. R., 32 Lexington Ave., Dayton 7, Ohio
Lloyd, A. T., 2223 N. Brighton St., Burbank, California
Longacre, H. C. Mc., 117 Eldred St., Williamsport, Pa.
Lorenz, R. J., Naval Ordnance Laboratory, Washington, D. C.
Lott, A. L., Tait Rd., Old Greenwich, Conn.
Lowden, R. W., 3a. Pembroke Bldgs., Park St., Camberley, Surrey, England
Mangini, F. A., Jr., 144–21—77 Ave., Flushing, L. I., N. Y.
Martowicz, C. T., 116 E. Seventh St., New York, N. Y.
Mason, G. D., 1011 W. 34 St., Los Angeles 7, California
McClain, H. C., 1839 N. 53 St., Seattle 5, Wash.
McDade, Everest, c/o Southland News Co., Chattanooga, Tenn.
McMordie, F., 86-A Yorkway, Dundalk, Baltimore 22, Md.
Mikell, W. G., 1505 Lady St., Columbia 7, S. C.
Miller, H. M., 1001 Elmire St., Williamsport 13, Pa.
Millington, J. W., 2237 Calder Ave., Beaumont, Texas

*(Continued on page 42A)*

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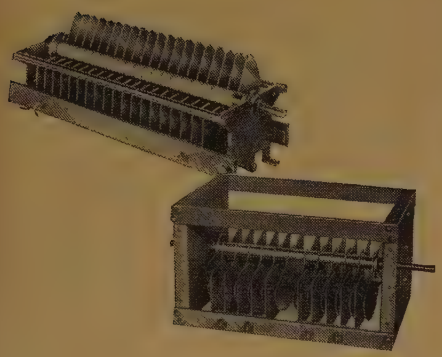

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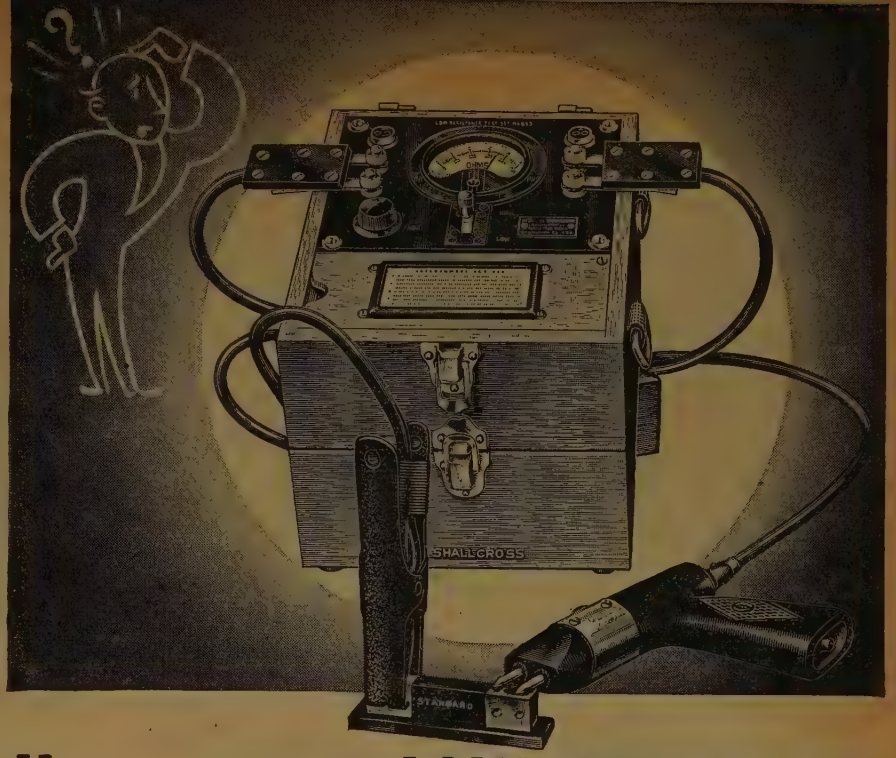


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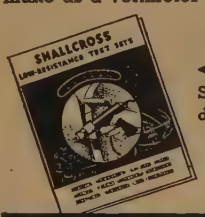


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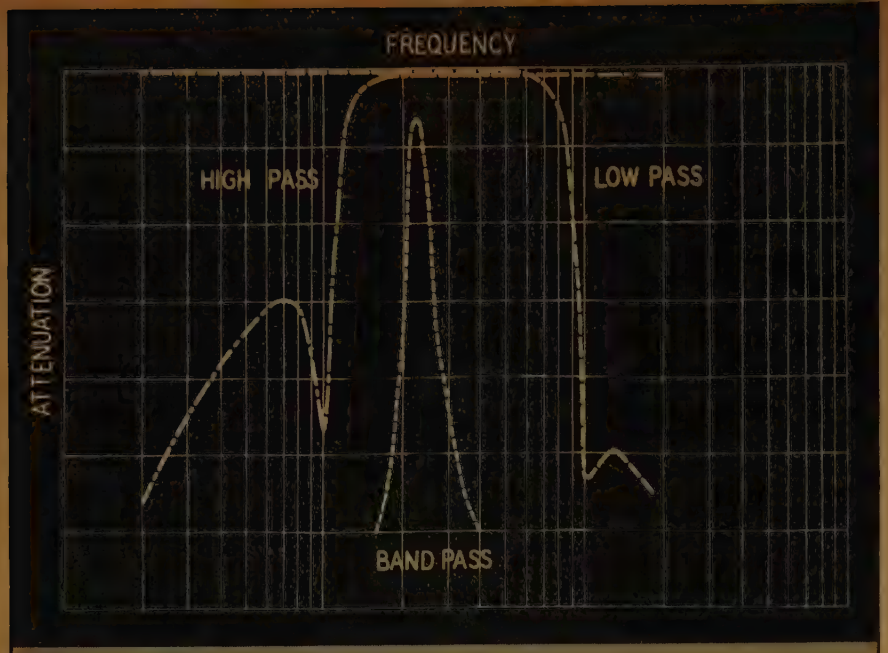


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O'Brien, F. B., 16037 Junaluska Way, Pacific Palisades, Calif.
Offner, A., 1596 W. Seventh St., Brooklyn 4, N. Y.
Owens, W. R., 25 E. 9 St., Hialeah, Fla.
Palmer, N. R., c/o National Broadcasting Service Box 3045, Wellington, C. 1., New Zealand
Parkhurst, R. G., 2817 Connecticut Ave., N. W., Washington 8, D. C.
Picardy, P., 123–01—97 Ave., Richmond Hill 19, L. I., N. Y.
Pittenger, C. H., 309 N. Pike St., New Carlisle, Ohio
Porter, B. E., WSIX, Inc., Nashville Trust Bldg., Nashville 3, Tenn.
Porter, B. F., 1650 Bathurst St., Toronto, Ont., Canada
Pride, D. W., 110 Irving St., Cambridge 38, Mass.
Rankin, S. J., Rt. 3, Box 1366, Bremerton, Wash.
Rardin, V. E., RDM 1/c, Fleet P. O., New York, N. Y.
Rasche, D. O., 2214 Lincoln Ave., Granite City, Ill.
Raymond, N., 1667 Shadyside Rd., Baltimore 18, Md.
Secundino, R. D., Cangallo 1227, Buenos Aires, Argentina
Riley, D. H., 500 W. 112 St., New York 25, N. Y.
Robinson, A. J., Jr., 109 W. Fifth St., Emporium, Pa.
Roshon, J. R., 2570 Morse Rd., Route 3, Westerville, Ohio
Ruebhausen, V., 500 N. Elmhurst Rd., Prospect Heights, Ill.
Russell, J. D., Jr., KFQD, Anchorage, Alaska
Rylewicz, C., 1344 W. 18 Pl., Chicago 8, Ill.
St. Cyr, A. L., Box 44, Armonk, N. Y.
Samoluk, P., 11721—147 St., S. Ozone Park 20, L. I., N. Y.
Sarett, M., 51 Washington Village, Asbury Park, N. J.
Sayers, G. S., 34 Luxor View, Hare Hills, Leeds 8, Yorkshire, England
Seshadri, T. N., Presidency College, Madras, South India
Shattuck, H. L., 172 Burke Dr., Buffalo 21, N. Y.
Shaw, G. W., 1637 Fifth Ave., Oakland 6, Calif.
Sherr, J. B., 21 Pennsylvania Ave., Towson 4, Md.
Sinclair, D. C., 36 South Second St., Fairfield, Ohio
Skehan, J. W., Erskine Rd., R.F.D. 1, Stamford, Conn.
Smedley, C. F., 119 S. Williams St., Troy, Ohio
Smith, A. A., Route 1, Box 571, Selma, Calif.
Starr, J. O., 3 Hudson Ter., Dobbs Ferry, N. Y.
Stephens, E. T., 4274 St. Louis Ave., St. Louis 15, Mo.
Strock, R. L., 674 Jefferson Ave., Buffalo 4, N. Y.
Taylor, J. H., 243 Linden Ave., Towson 4, Md.
Taylor, J. J., 1212 Iona Ave., Wellston, St. Louis 14, Mo.
Teres, B. W., 2813 Boarman Ave., Baltimore 15, Md.
Wagner, L. P., Jr., 5302 Plymouth Rd., Baltimore 14, Md.
Waitkeneus, J., 111 Second Ave., N., Troy, N. Y.
Whitty, V. E., 111—75 Ave., Oakland, Calif.
Wunce, R. J., 3696 Maybelle Ave., Oakland 2, Calif.
Zelinger, G., Haifa, Box 1239, Palestine
Zeuschner, R. F., 5030 W. Altgeld St., Chicago 39, Ill.

**The names of Students transferred to the Associate Grade for the letters H through S. The letters A through G were published in the July, 1944, issue.**

Haden, James C., Cleveland Heights, Ohio
Haertig, Manfred M., Astoria, Oregon
Halpern, Robert L., Philadelphia, Pa.
Haney, Ralph W., Washington, 20, D. C.
Hardenbergh, George A., St. Paul, Minn.
Harrell, Bert F., Cambridge, Mass.
Harrell, John W., Wichita, Kan.
Harris, F. H., Jr., Bellevue, D. C.

*(Continued on page 45A)*

# Membership

*(Continued from page 42A)*

Hartford, Walter W., Jr., Newtonville, Mass.
Hartley, Harry F., Jr.,Philadelphia, Pa.
Hastings, Henry A., Hasbrouck Heights, N. J.
Hazelwood, Charles F., Jr., Schenectady, N. Y.
Herman, Jerome B., Glendale, Calif.
Hersh, John F., Cambridge, Mass.
Hickey, John S., Jr., Bronx, N. Y.
Himes, B. T., Jr., West Palm Beach, Fla.
Himmel, Leon, New York, 53, N. Y.
Hodder, Wayne K., Cambridge, 39, Mass.
Hoglund, Ralph H., Cambridge, Mass.
Holzman, George R., Richmond Hill, L. I., N. Y.
Hornberg, Kenneth O., Washington, D. C.
Houck, G. B., Jr., Port Chester, N. Y.
Hu, Han Chuan, Lancaster, Pa.
Huggins, W. H., Corvallis, Ore.
Iliffe, Francis H., Montreal W., Que., Canada
Ittelson, William H., New York, N. Y.
Jackson, Robert Jr., Philadelphia, Pa.
Jaeger, Carl H., Los Angeles, Calif.
James, Edward W., New York, N. Y.
James, Samuel D., Lyle, Wash.
Janney, Douglas B., Schenectady, N. Y.
Jazwa, John J., San Francisco, Calif.
Johns, Carol N., Cambridge, 38, Mass.
Johnson, Charles Y., Arlington, Va.
Johnson, Warren C., Bloomfield, N. J.
Johnston, Stephen L., Atlanta, Ga.
Jones, Clarence W., Boston, Mass.
Jones, Ernest A., Pomeroy, Ohio
Jones, Richard C., Arlington, 74, Mass.
Joy, Clyde R., Jr., Keokuk, Iowa
Kan, George, Washington, D. C.
Katch, Michael, Montreal, Que., Canada
Kauke, John R., Washington, 20, D. C.
Keene, Robert E., Pensacola, Fla.
Kelly, R. D., Mobile, 3, Ala.
Kelsey, James R., St. Paul, Minn.
Kerby, Gordon A., Larchmont, N. Y.
Kerr, William, Jr., Knoxville, Tenn.
Kiyokawa, Siegeo, Philadelphia, 19, Pa.
Klaus, George H., St. Albans, L. I., N. Y.
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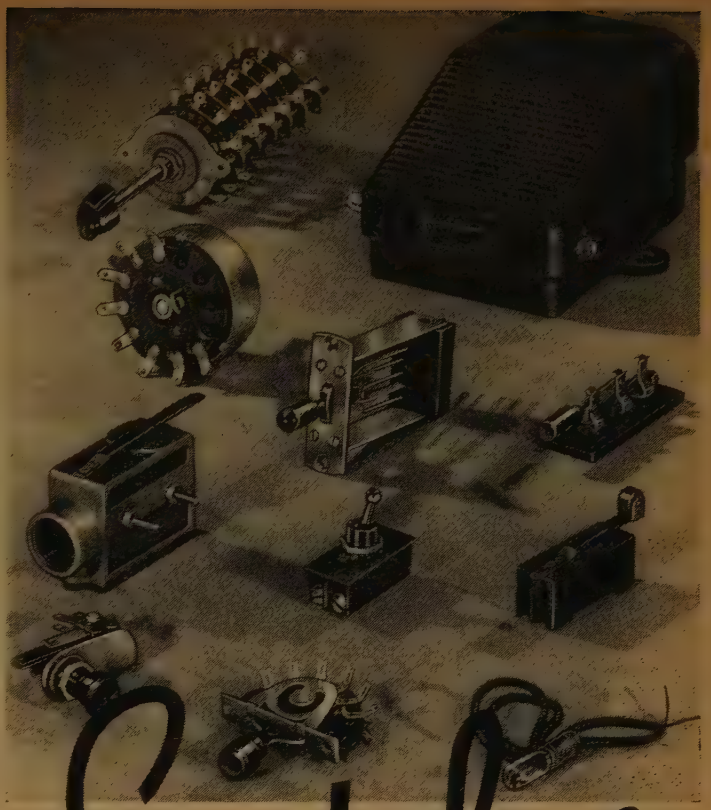
McDowell, James M., Pittsburgh, Pa.
Michaelson, Merton W., Bremerton, Wash.
Middlecoff, Harry W., Silver Spring, Md.

*(Continued on page 46A)*



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*(Continued on page 56A)*

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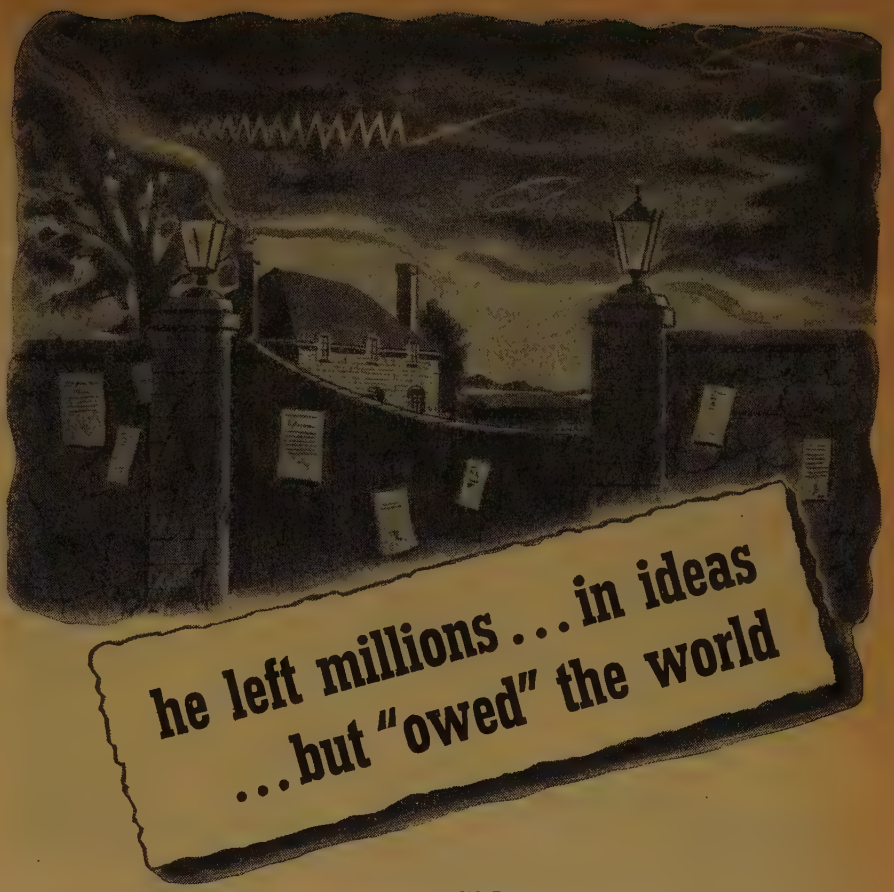

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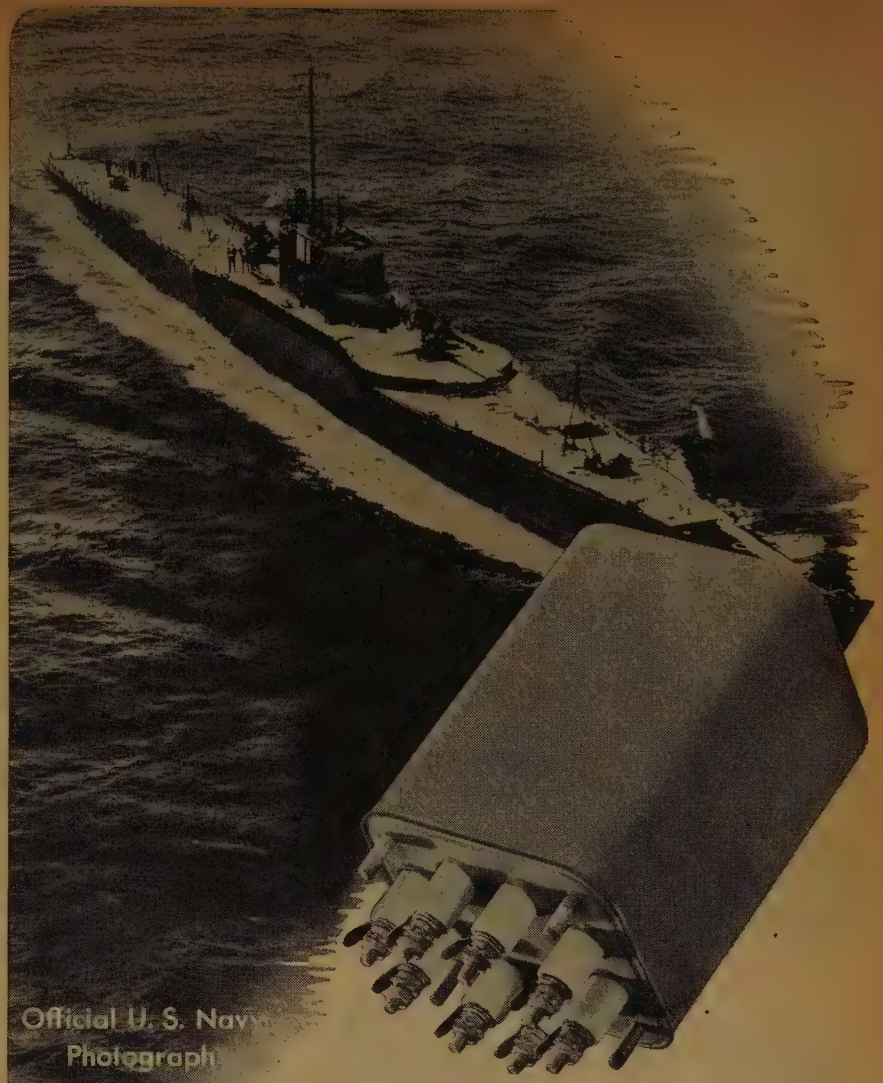


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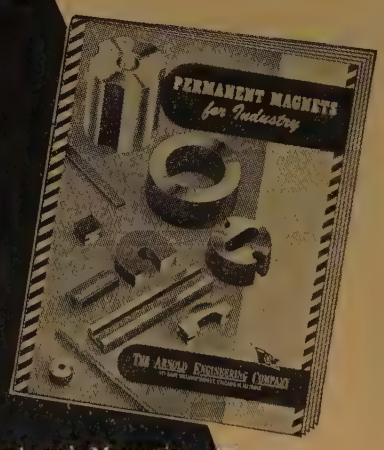


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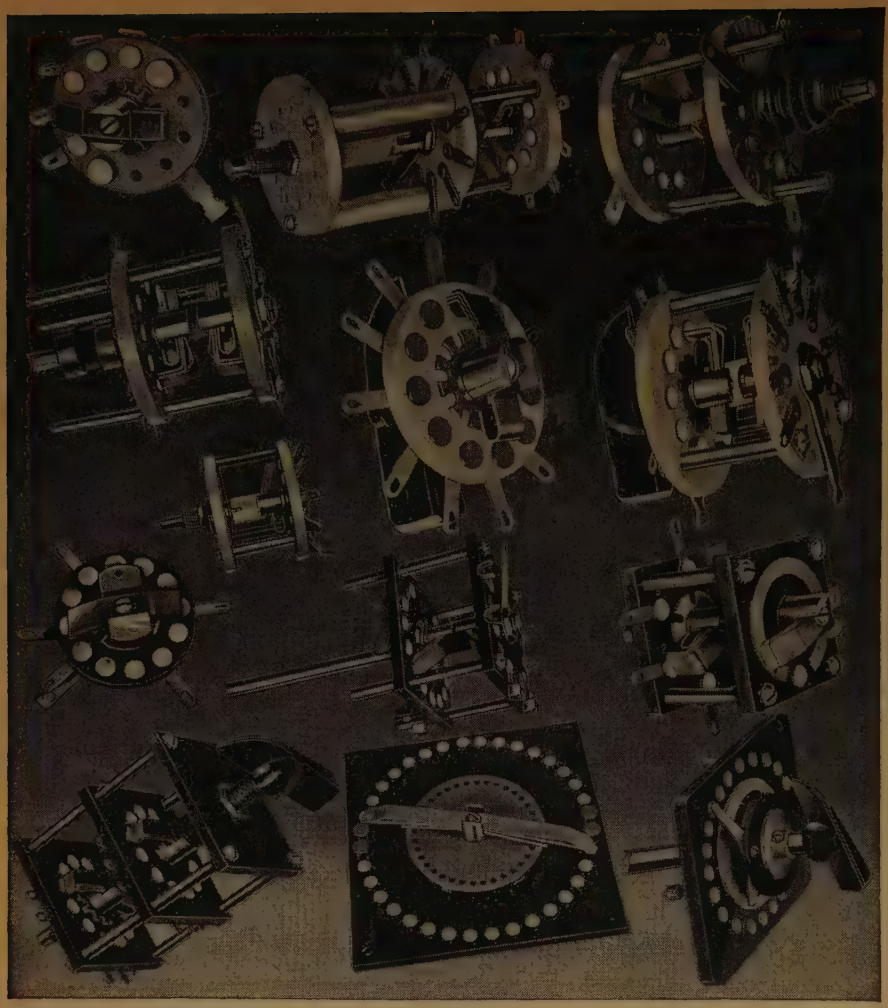

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## SECTION MEETINGS

BALTIMORE

"Aircraft Radio Power-Supply Apparatus," by C. K. Hooper, Westinghouse Electric and Manufacturing Company; June 20, 1944.

Election of Officers; June 20, 1944.

BOSTON

"Coupled Circuits," by H. M. Turner, President; Institute of Radio Engineers; April 14, 1944.

"Frequency Modulation on Mount Washington," by I. B. Robinson, Station WNAC; May 19, 1944.

"Studio Acoustics," by S. A. Waite, Station WNAC; May 19, 1944.

BUENOS AIRES

"Measurements on Lines at High Frequencies," by E. Labin, Philips, June 6, 1944.

"The Doherty Amplifier," by F. Harris, Standard Electric Company, June 22, 1944.

DALLAS-FT. WORTH

"The Principles and Application of Electron Microscopy," by W. J. Yost, Magnolia Petroleum Company; July 12, 1944.

"The Electrical Circuits and Operating Techniques with the RCA-Type Electron Microscope," by P. P. Reichertz, Magnolia Petroleum Company; July 12, 1944.

INDIANAPOLIS

"Ultra-High-Frequency Measurements," by E. D. Cook, General Electric Company; April 28, 1944.

"Frequency Modulation and Television," by R. F. Guy, National Broadcasting Company; May 26, 1944.

"Very-High-Frequency Applications of Radio Guides and Airport Facilities," by W. E. Jackson and P. D. McKeel, Civil Aeronautics Authority; June 23, 1944.

KANSAS CITY

"The Electron Microscope and Its Applications," by M. C. Banca, Radio Corporation of America; March 28, 1944.

"Electronic Applications in the Paper Manufacturing Industry," by Lowell Zabel, Wilcox Electric Company; May 31, 1944.

Election of Officers; May 31, 1944.

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**The following transfers and admissions were approved on August 2, 1944.**

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George, R. W., R.C.A. Laboratories, Riverhead, N. Y.
Kandoian, A. G., 67 Broad St., New York, 4, N. Y.
Miller, B. F., 2845 Russell St., Berkeley 5, Calif.
Palmquist, J. F., 3807 Somerset Dr., Los Angeles, Calif.
Ware, P., 8 Glenside Ter., Upper Montclair, N. J.

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Bowden, B. V., C.R.G., Naval Research Laboratory, Anacostia Station, D. C.
Graner, L. P., 40 E. 49 St., New York, 17, N. Y.
Holloway, F. L., 432 Sandhurst Dr., Dayton, 5, Ohio.
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*(Continued on page 36A)*

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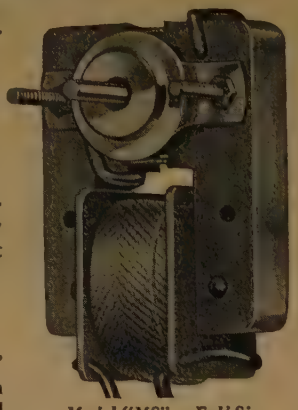

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Our long established standards of precision manufacturing from highest grade materials are strictly adhered to in these models to insure long life without breakdowns.

### EFFICIENT

Both the new Model "K" Motor and the Model "MS" are the shaded pole induction type — the last word in efficient small motor design. They can be produced in all standard voltages and frequencies with actual measured power outputs ranging upwards to 1/100 H. P. . . Alliance motors also can be furnished, in quantity, with variations to adapt them to specific applications.

*New Model "K"— Full Size*
*Motor Measures*
$2\frac{1}{8}$" x $2\frac{3}{8}$" x $3\frac{1}{16}$"

### DEPENDABLE

Both these models uphold the *Alliance* reputation for all 'round dependability. In the busy post-war period, there will be many "spots" where these Miniature Power Plants will fit requirements . . . Write now for further information.

*Remember Alliance!*
—YOUR ALLY IN WAR AS IN PEACE

ALLIANCE
MANUFACTURING CO.
ALLIANCE . OHIO


## MEMBERSHIP

*(Continued from page 34A)*

Singer, F. J., 234 N. Forest Ave., Rockville Centre, L. I., N. Y.

### Transfer to Member

Arcand, W., 100 Third St., Wood-Ridge, N. J.
Barnes, F. P., Box 1858, Seattle, Wash.
Brace, F. R., 1258 La Playa, San Francisco, Calif.
Brown, W. N., Jr., 747 S. Monroe St., Xenia, Ohio.
Burroughs, H. A., 2124 Key Blvd., Arlington, Va.
Hill, W. R., Jr., University of Washington, Seattle 5, Wash.
Jacobs, M., 171 E. Hillcrest Ave., Dayton 5, Ohio.
Johnson, H. D., Box 175, R.F.D. 2, Emporium, Pa.
Kees, A. A., 1435 Ulloa St., San Francisco, Calif.
Klipsch, P. W., Southwestern Proving Ground, Hope, Ark.
Marston, R. S., 23 Flint Ave., Hempstead, L. I., N. Y.
Rappaport, G., 3522 S. Utah St., Arlington, Va.
Richmond, L. P., 144 Forrer Blvd., Dayton, Ohio.
Weston, S., 365 W. 20 St., New York, N. Y.

### Admission to Member

Bass, H., 7363 Clovernook Ave., Mt. Healthy, Ohio.
Bechtol, H., Airplane and Marine Instruments, Inc., Clearfield, Pa.
Berg, S., 74 Barker Ave., Eatontown, N. J.
Cohen, J. S., 1514 Teakwood Ave., Cincinnati, Ohio.
Folland, D. F., 100 Anchor Way, East Hempstead, L. I., N. Y.
Hansen, C. A., 153 Norfolk Ave., Clarendon Hill, Ill.
Horvath, A., 52 Webster St., Lynbrook, L. I., N. Y.
Iversen, R. J., 36–01—31 Ave., Long Island City, L. I., N. Y.
Kiss, J. S., 2250 Cathedral Ave., Norwood, Ohio.
Langstaff, R. H., 6145 Glade Ave., Cincinnati, Ohio.
Meador, B. M., 520 W. Fairview Ave., Dayton, Ohio.
O'Bryan, H., 3297 Worthington St., N. W., Washington, D. C.
Peterson, L. J., Aircraft Radio Laboratory, Wright Field, Dayton, Ohio.
Reyling, P. M., 50 N. Munn Ave., East Orange, N. J.
Sobel, A. D., 2939 Ocean Ave., Brooklyn, N. Y.
Tyrrell, W. A., Box 107, Red Bank, N. J.
Van Horn, R. H., 463 West St., New York 14, N. Y.

**The following transfers and admissions of membership have been approved by the Admissions Committee. Objections to any of them should reach the Institute office by not later than September 29, 1944.**

### Transfer to Senior Member

Anton, N. G., 225 Sterling Pl., Brooklyn, N. Y.
Beam, R. E., Northwestern University, Evanston, Ill.
Greig, D. D., 106–15 Queens Blvd., Forest Hills, L. I., N. Y.
Christaldi, P. S., 132 Squire Hill Rd., Upper Montclair, N. J.
Corbett, C. W., 333 E. 53 St., New York, N. Y.
DeVore, L. T., 1245 Arbor Ave., Dayton, Ohio.
Donovan, W. E., 40 E. 49 St., New York, N. Y.
Everest, F. A., 1011 Encino Row, Coronado, Calif.
Gubin, S., 4417 Pine St., Philadelphia, Pa.
MacLean, K. G., R.C.A. Laboratories, Riverhead, L. I., N. Y.
Noble, D. E., 165 Garfield Ave., Elmhurst, Ill.
Ostlund, E. M., 194 Grove St., Montclair, N. J.
Ramo, S., General Electric Company, Schenectady, N. Y.
Scheer, G. H., Jr., R.F.D. 5, Box 379, Dayton, Ohio.
Wentz, J. F., 180 Varick St., New York, N. Y.
Wright, J. W., 122 Webster Ave., Manhasset, L. I., N. Y.

*(Continued on page 38A)*

In designing a new electronic tube, mathematical calculations are invaluable, but as every designer knows, they are but preliminaries. After them, there usually come many tests of various experimental tubes. Machlett thought the cut-and-try method not only wasteful, but not productive of the best results. So we shortened and simplified the procedure by what our laboratory people call the "rubber model."

Here is a stretched rubber sheet. At the high end is a model of the cathode (electron emitter) of a proposed tube, and at the other end the anode, or target of an X-ray tube, plate of an oscillator or rectifier. The slope between the two is proportional to the desired potential difference. By means of an electro-magnet, a steel ball can be held in any position along the cathode, then released to roll under gravity to the anode, where the point it strikes can be observed and measured. *This is an electro-mechanical analogy.*

By means of this rubber model technique, months have been shortened into days, weeks into hours. More than that, new and higher performance has been achieved in the final product, so that when you buy a Machlett tube, you are assured of precise results, longer life, greater economy . . . Machlett Laboratories, Inc., Springdale, Connecticut.

*The Machlett 880 is a radio oscillator tube for use in transmitters, and has a maximum output of 60 KW.*

MACHLETT

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**REMLER IS EQUIPPED** with facilities for the mass production of complete announcing and amplified sound transmitting equipment; radio; plugs and connectors. Skilled technicians and vigilant inspectors check and re-cneck final products to meet rigid specifications. The facilities of this organization backed by twenty-five years of experience in the manufacture of electronic products and plastics, is at your disposal for further assignments.

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| Types: | | PL | | |
|---|---|---|---|---|
| 50-A | 61 | 74 | 114 | 150 |
| 54 | 62 | 76 | 119 | 159 |
| 55 | 63 | 77 | 120 | 160 |
| 56 | 64 | 104 | 124 | 291-A |
| 58 | 65 | 108 | 125 | 354 |
| 59 | 67 | 109 | 127 | |
| 60 | 68 | 112 | 149 | |

| PLP | | PLQ | | PLS | |
|---|---|---|---|---|---|
| 56 | 65 | 56 | 65 | 56 | 64 |
| 59 | 67 | 59 | 67 | 59 | 65 |
| 60 | 74 | 60 | 74 | 60 | 74 |
| 61 | 76 | 61 | 76 | 61 | 76 |
| 62 | 77 | 62 | 77 | 62 | 77 |
| 63 | 104 | 63 | 104 | 63 | 104 |
| 64 | | 64 | | | |

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**Other Designs to Order**

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*Announcing & Communication Equipment*


## MEMBERSHIP

*(Continued from page 36A)*

### Admission to Senior Member

Sherman, V. W., Federal Telephone and Radio Corporation, 200 Mt. Pleasant Ave., Newark. N. J.

Duffendack, O. S., North American Philips Company, Richmond Hill, Irvington-on-the-Hudson, N. Y.

### Transfer to Member

Campbell, M. E., A.P.O. 518, c/o Postmaster. New York, N. Y.

Deerhake, F. M., 600 Oakwood St., Fayetteville. N. Y.

Edwards, H. H., 186–21—122 Ave., St. Albans, L. I., N. Y.

Ellithorn, H. E., 417 Parkovash Ave., South Bend 17, Ind.

Espy, W. D., 362—30 Street Dr., S. E., Cedar Rapids, Iowa.

Fernandez, M., 20 Ferrying Group A.T.C., Municipal Airport, Nashville, Tenn.

Fiedler, L., 53 Rosedale, Hamburg, N. Y.

Gorman, D. P., E. 521 Sharp Ave., Spokane, Wash.

Graf, A. W., 4 Midway Ct., Hammond, Ind.

Hirsch, O. C., 324 Broadway, Cape Girardeau, Mo.

McCartney, H S., 625 Second Ave., S., Minneapolis 2, Minn.

Sharp, W. O., Bell Telephone Laboratories, 395 Hudson St., New York, 14, N. Y.

Sokoloff, P. W., 68–19 Burns St., Forest Hills, L. I., N. Y.

Squires, E. G., 319 E. Jefferson Ave., Wheaton, Ill.

Stockman, H., Cruft Laboratory, Harvard University, Cambridge 38, Mass.

Thomas, H. P., 202 Huntleigh Ave., Fayetteville. N. Y.

Wang, T. S., 726 Cooper St., Camden, N. J.

Whinnery, J. R., 2047 Coolidge Pl., Schenectady, N. Y.

Williamson, R. H., 161 E. Onondaga St., Syracuse 2, N. Y.

### Admission to Member

Curtis, R. C., 25 Stanley St., New Haven, Conn.

Davis, F. M., 1429 Wildwood Dr., N. E., Cedar Rapids, Iowa.

Feldt, R., 875 W. 181 St., New York 33, N. Y.

Hackett, A. H., Apartado 1226, Telephone Co., Caracas, Venezuela, S. A.

Laning, W. A., 70 Glen Ridge Ave., Glen Ridge, N. J.

Norman, S. W., 300 Buxton Rd., Falls Church, Va.

Warner, A. W., Jr., Bell Telephone Laboratories, Murray Hill, N. J.

Weid, A. C., Airborne Instruments Laboratory, 150 Old Country Rd., Mineola, L. I., N. Y.

Weissman, S., 321 W. Norman Ave., Dayton 5, Ohio.

**The following admissions were approved on August, 2, 1944.**

### Admission to Associate

Artman, R. G., 37 Langdon St., Cambridge, 38, Mass.

Athersych, F. B., 129 High St., London, Ont., Canada

Ault, C. M., RR. 9, Box 618, Indianapolis, 44, Ind.

Axel, P., 1 Queensberry St., Boston, Mass.

Baker, W. K., 425 Peachtree St., N.E., Atlanta, 3, Ga.

Bauman, A. M., 3701 N. Lowell Ave., Chicago, Ill.

Beach, G. E., R.C.A.F., Clinton, Ont., Canada

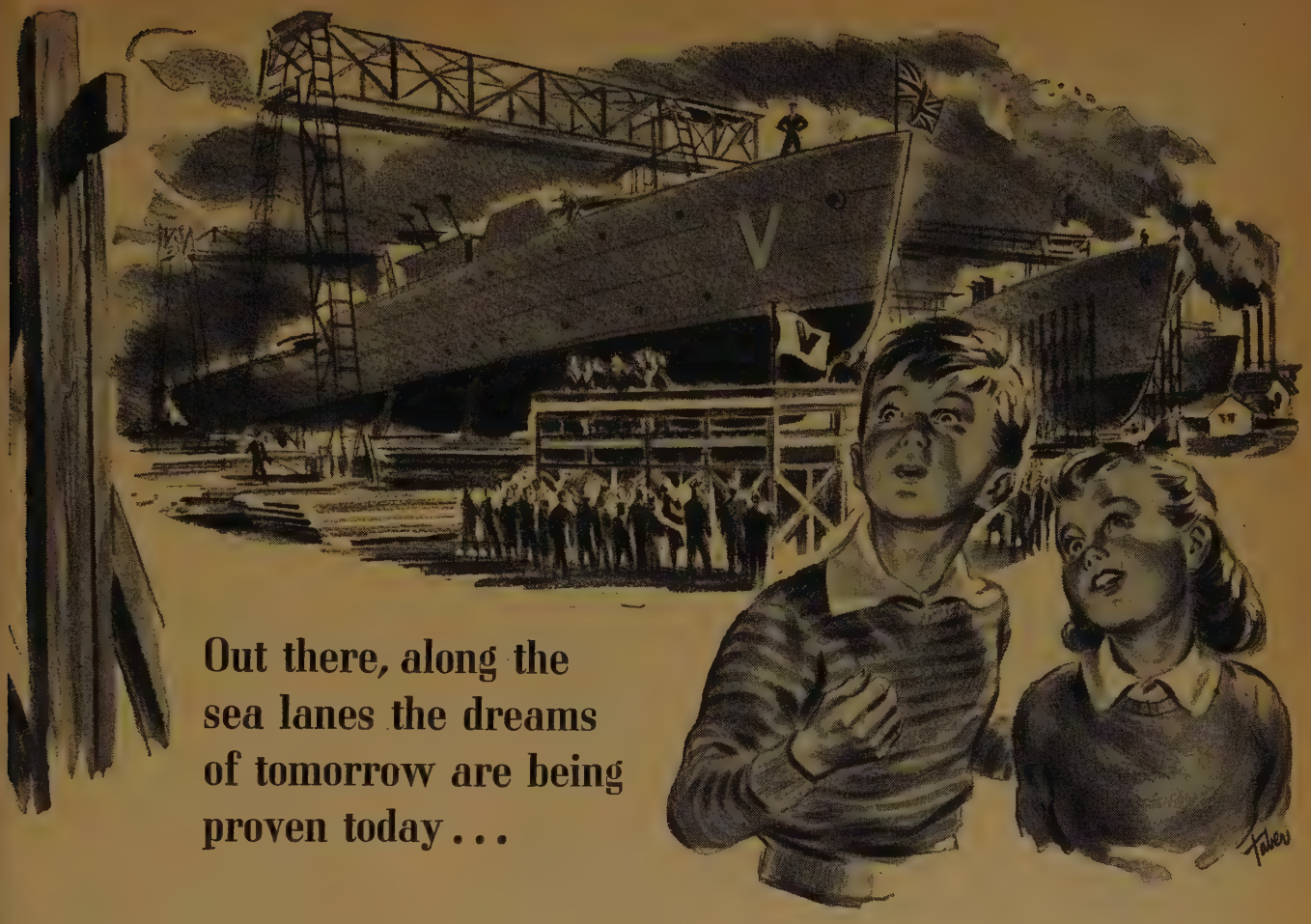
Berge, O. L., 2057 S. 73 St., Milwaukee, 14, Wis.

Biedenbender, R., 5658 Lawndale Pl., Cincinnati, 13, Ohio

Birrell, A., c/o Divisional Engineer, General P. O., Cape Town, South Africa

*(Continued on page 40A)*

# WHERE TOMORROW MEETS TODAY



**Out there, along the sea lanes the dreams of tomorrow are being proven today . . .**

CORVETTES "turn on a dime"—destroyers race at abnormal speed—that's the navy of today! Mastery of the sea depends on new and ever-improved equipment.

Today on our fighting ships, many pieces of electrical apparatus are designed and produced by Small Electric Motors (Canada) Limited. At the moment we are devoting all our efforts to turning out material of an advanced scientific nature. Research, engineering and inventive genius work hand in hand to produce equipment that normally would be much longer in developing.

In the days to come you may wish to benefit by this "know-how." These experiments and achievements in technical war contributions will be reflected and recognized in the electrical world of tomorrow. Small Electric Motors plan with confidence a noteworthy role in the post-war era.

**DESIGNERS**
**AND MANUFACTURERS**
**Of All Types of Precision Electrical Apparatus Including:**

*D.C. & A.C. Motors for Specialized Purposes*
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*Aircraft Engine Starters*
*Alternators*
*Motor Generators*
*Electric Pumps*
*Motors with Governors*
*Gyros, etc.*

2-44

**SMALL Electric Motors**
**(CANADA) LIMITED**

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# TRANSFORMERS HELP THEM WIN!

All important to a Task Force are the many and varied electrical units that play such a vital part in the operating and coordinating of both ships and planes.

One factor common to all these units is the need of an unfailing source of Proper Power—the Hermetically Sealed Transformer.

Chicago Transformer designs and manufactures transformers that more than meet the rigid standards set for equipment of this type.

Official U. S. Navy Photograph

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DIVISION OF ESSEX WIRE CORPORATION

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CHICAGO, 18


## MEMBERSHIP

*(Continued from page 38A)*

Bishop, J. C., Jr., Instructors' Co., Bks. 10., N.A.T.T.C., Ward Island, Corpus Christi, Texas
Bolton, J. J., Mary St., Clinton, Ont., Canada
Bonness, Q. L., 1418 Union St., Schenectady, N. Y.
Brown, W. T., 1123–26 Ave., Seattle, 22, Wash.
Byers, V. J., Box 368, Clinton, Ont., Canada
Carvin, E. A., 47–31–37 St., Long Island City, L. I., N. Y.
Ceccanti, L. P., c/o Fleet Post Office, New York, N. Y.
Chandler, H. J., Radio Station KRNR, Roseburg, Ore.
Cholmondeley-Smith, D. R., Clyde Rd., Browns Bay, Auckland, N. 3., New Zealand
Collins, G. A., Clinton, Ont., Canada
Coughlin, V. L., Box 445, Clinton, Ont., Canada
Crane, N. B., Sig. Detachment S. C., Aircraft Signal Agency, Wright Field, Dayton, Ohio
Crosson, W. J. R., North St., Clinton, Ont., Canada
Cummings, S. J., 130 Walnut St., Saratoga Springs, N. Y.
Davis, H., 4946 Camden St., Indianapolis, 3, Ind.
Diamond, S., 63 Brunswick Ave., Toronto, Ont., Canada
Dobbin, R., Box 492, Manasquan, N. J.
Downing, J. T., 150 South St., Jamaica Plain, 30, Mass.
Draganjac, M. J., 54 W. Hudson Ave., Dayton, Ohio
D'Orio, A. F., 42 N. Menard Ave., Chicago, Ill.
Ellenwood, R. C., RFD, Wooster, Ohio
Elwell, D., 10 Rockefeller Plaza, New York, N. Y.
Fleisher, H., 43 Irving St., Cambridge, 38, Mass.

*(Continued on page 42A)*


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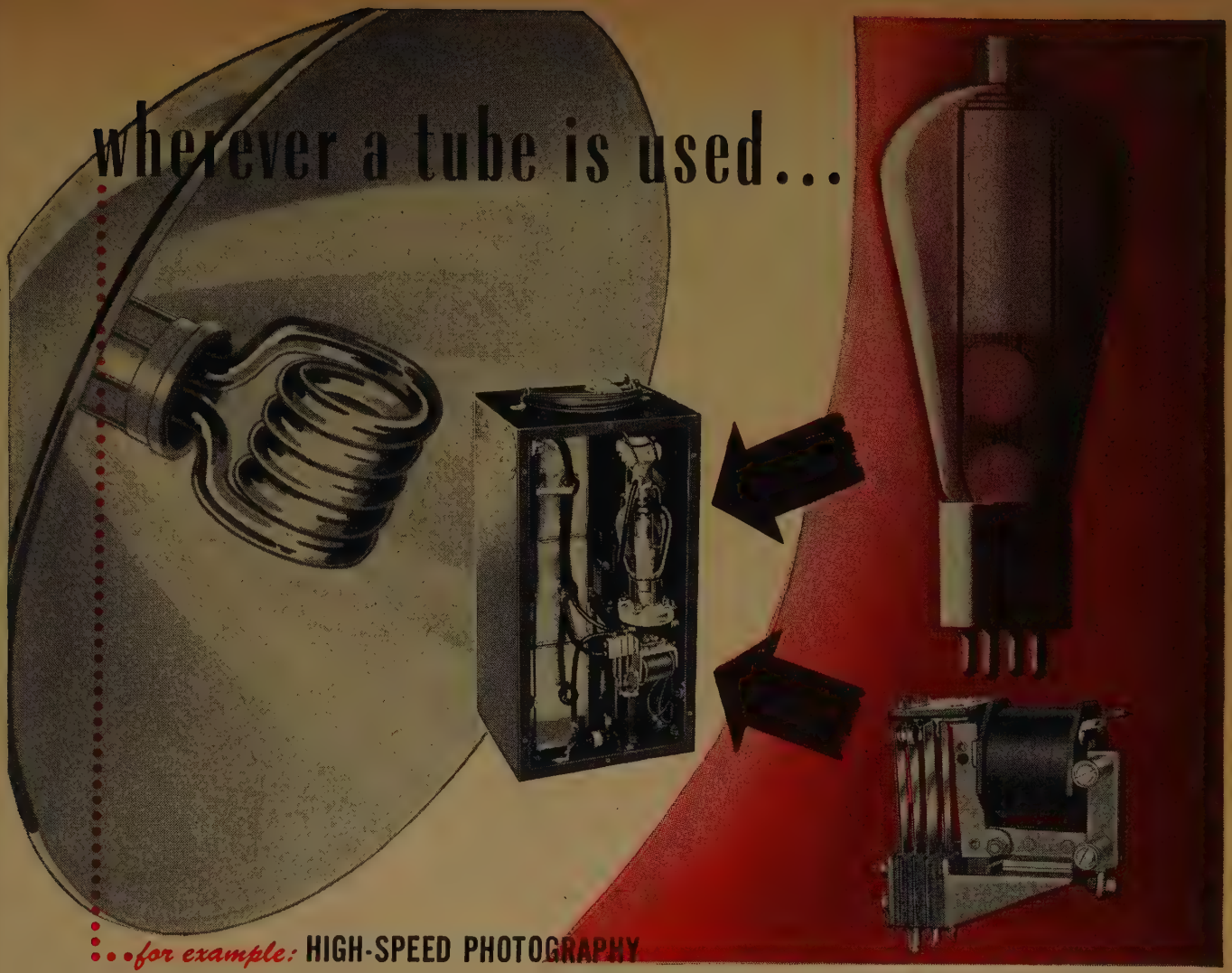
## SUN RADIO & ELECTRONICS CO.

212 Fulton Street, New York 7, N. Y.

# wherever a tube is used...



...*for example:* HIGH-SPEED PHOTOGRAPHY

The Lee Strobo-Speed lamp stops action of rapid movement with a flash of about one thirty-thousandth of a second. One flash exceeds in light intensity the illumination of 2,000 kilowatts of ordinary tungsten lamps. Operates on 115 volts, 60 cycles, A.C.

THERE'S A JOB FOR

## *Relays* BY GUARDIAN

In the Lee Strobo-Speed lamp a rectifier tube is employed to build up a high charge on a bank of condensers. These are discharged through the flash lamps when the Guardian Series 15 relay is energized. This special application illustrates the flexibility of design incorporated into Guardian relays. The Guardian standard Series 15 was selected for the job and engineered to meet the high voltage requirements and other special conditions.

Another Lee Strobo-Speed unit with three flash tubes operating from three banks of condensers also employs the Series 15 relay. In this application the relay is equipped with additional switches to handle three circuits instead of one. Contact switches in both units are specially insulated to withstand the high voltages.

The Series 15 is a compact unit having a maximum switch capacity of 10 pole, single throw with 1½ amp. contacts; 6 pole single throw with 8 amp. contacts; 4 pole double throw with 12½ amp. contacts. Coils for standard voltages range up to 220 volts and may be equipped with copper slug time delay on release or attract.

Single Flash Tube, Single Circuit Diagram.

Consult Guardian whenever a tube is used—however, Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

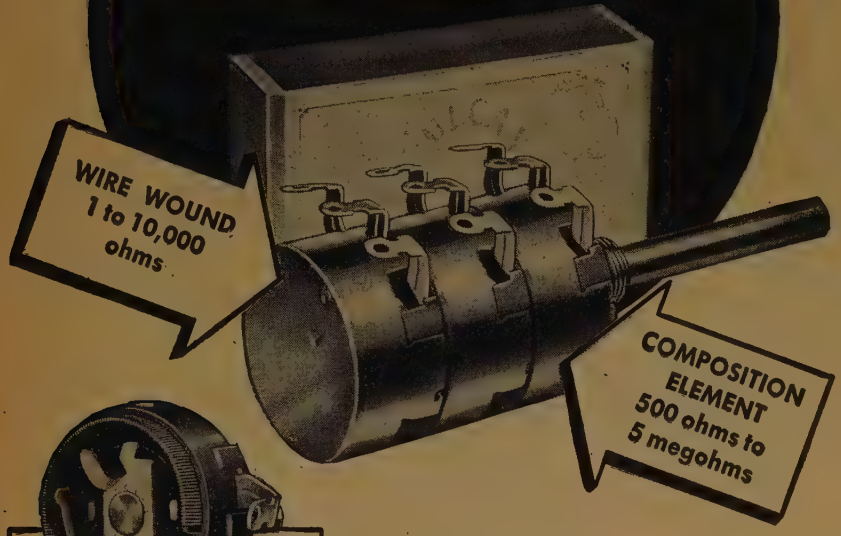
For D. C.—write for Series 15 bulletin. For A. C.—write for Series 30 bulletin.

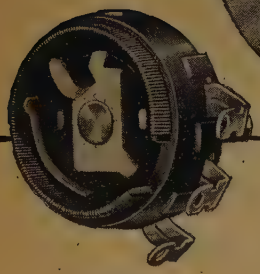
**GUARDIAN ELECTRIC**

1628-K W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

# Matched
## MIDGET CONTROLS



*New*

***Clarostat Type 43***
**WIRE-WOUND MIDGET**

Smallest unit now available of that rating.

* * *

Rated at 2 watts. 1 to 10,000 ohms.

* * *

Matches Clarostat Type 37 midget composition-element control—in appearance, dimensions, rotation, switch.

* * *

Available with or without power switch.

* * *

Available in tandem assemblies—suitable combinations of wire-wound and composition-element controls.

* * *

Type 37 composition-element controls rated at ½ watt. 500 ohms to 5 megohms.

★ They look, measure and operate the same—these Clarostat wire-wound and composition-element midget controls. Fully interchangeable, mechanically. Can be made up in various tandem assemblies.

Clarostat Type 37 midget *composition-element* controls have been available for several years past. Their *stabilized* element has established new standards for accurate resistance values, exceptional immunity to humidity and other climatic conditions, and long trouble-proof service.

And now the Clarostat Type 43 midget *wire-wound* control is also available, to match Type 37—matched in appearance, dimensions, rotation, switch.

For neatness, compactness, convenience, trouble-free operation—just specify these Clarostat *matched midget controls.*

★ *Write for literature. Submit that resistance or control problem. Let us quote on your requirements.*

CLAROSTAT *Controls and Resistors*

CLAROSTAT MFG. CO., Inc. · 285-7 N. 6th St., Brooklyn, N. Y.


## MEMBERSHIP

*(Continued from page 40A)*

Fouts, J. L., 827 Seventh St., Bremerton, Wash.
Fox, C. A., R.C.A.F., Clinton, Ont., Canada
Frank, N. E., 3101 W. Grand Blvd., Detroit, Mich.
Fraser, E. R., American Telephone & Telegraph Co., Box 301, West Haven, Conn.
Fry, P. F., 1503 Bolton St., Baltimore, 17, Mass.
Gale, G. G. H., R.C.A.F., Clinton, Ont., Canada
Gallo, J. M., c/o Fleet Post Office, New York, N. Y.
Garcia, J. H., 4731 E. 16 St., Indianapolis, Ind.
Gausewitz, C. H., 1500 Oak Ave., Evanston, Ill.
Grant, E. F., 1039 S. Braddock Ave., Pittsburgh, 18, Pa.
Green, D. J., 4530–38 St., San Diego, 4, Calif.
Green, W. B., General Delivery, Clinton, Ont., Canada
Groves, R. M., 1125 Briarcliff Pl., N.E., Atlanta, Ga.
Hageman, K. G., 315 Parkland Pl., S.E., Washington, 20, D. C.
Hall, D. J., 2600 W. 50 St., c/o Majestic Radio and Television Corp., Chicago, 32, Ill.
Hardcastle, C., 167 Lichfield Rd., Bloxwich, Walsall, England
Harmon, A. L., 405 Condon Ter., S.E., Washington, 20, D. C.
Harper, H. F., Signal Detachment, Signal Corps, Aircraft Signal Agency, Wright Field, Dayton, Ohio
Heininger, W. W. L., 508 W. 114 St., Apt. 82A, New York, N. Y.
Hoover, W. G., 586 Foothill Rd., Stanford University, Calif.
Hopkins, J. E., 510 North St., East Aurora, N. Y.

*(Continued on page 44A)*


**PLATINUM**
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**TUBING**

**For all Electronic Applications**

**Platinum metals scrap and residues refined and reworked on toll charges; or purchased outright by us . . .**

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44 GOLD ST. · NEW YORK
SINCE 1901

# 14 YEARS OF AVIATION RADIO

In 1930 airplanes were "crates." Wire, cloth, slats. Mostly biplane. Wonderful, but fearful. Compare these old machines with the streamlined, compact safety models of today.

Year by year aviation radio has kept pace. Matched progress. Produced RCA aircraft radio that is lighter, that does more, that is more dependable.

For example, shown above is an RCA aircraft receiver of 1930. The equivalent RCA 1944 equipment, also shown, is less than one-eighth as bulky and one-fifth as heavy. Yet it does a far better job and provides two frequency ranges (550 to 1500 kc. and 195 to 450 kc.), instead of the one range available with the 1930 apparatus.

This is a typical example of RCA initiative and ability in developing improved radio equipment. In the years to come this progress will be maintained in further development of RCA aviation radio that meets the most exacting requirements of military, transport and light plane service.

RCA

**RADIO CORPORATION OF AMERICA**

**RCA VICTOR DIVISION**

**CAMDEN, N. J**

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## OF RECTIFIERS AND PHOTOTUBES
# CETRON

Particularly sensitive to blue and violet light. RMA spectral sensitivity designation S-4. 5-Pin base interchangeable with other similar tubes.

Rectifier designed to meet rigid Army and Navy specifications. Incorporates numerous improvements insuring efficiency, ruggedness and long-life.

Grid control Rectifier (Thyratron) especially suited for industrial use, such as handling primary currents of small resistance welders—motor control, etc.

CE-235 is a half wave Argon-filled Rectifier with screw base, sturdily constructed for long, dependable service.

Cetron Rectifiers are available in gas and mercury filled, both full, and half wave types in a wide range of ratings.

Cetron Phototubes are produced by us to take care of almost every situation . . . over 50 types, both blue and red sensitivity.

Continental's long experience and careful production methods insure you the utmost in satisfaction from all the many types of tubes we make. Write for complete catalog.

# CONTINENTAL ELECTRIC COMPANY GENEVA, ILL.

★ CHICAGO OFFICE, 903 Merchandise Mart
NEW YORK OFFICE, 265 West 14th Street


## MEMBERSHIP

*(Continued from page 42A)*

Hosking, W. J. C., 40 King St., Clinton, Ont., Canada
Howard, W. A., 7528 Thouron St., Philadelphia, 38, Pa.
Howells, P. W., 1112 Parkwood Blvd., Schenectady, 8, N. Y.
Hoyt, W. S., Farnsworth Television & Radio Corp., Fort Wayne, Ind.
Hunka, D., R.C.A.F., Clinton, Ont., Canada
Jefferies, D. W., Radio Station WTBO, Cumberland, Md.
Hunter, G. E., 75 Murray Ave., Greenfield Park, Que., Canada
Jensen, R. S., 306C Talbot Lab., University of Illinois, Urbana, Ill.
Kaplan, M., 806 AAF Base Unit, Sec. B, Bks. 206, Baer Fd., Fort Wayne, Ind.
Kennedy, R. J., 217 W. Lake St., Barrington, Ill.
Komm, J., 223 W. 115 St., Chicago, 28, Ill.
Klibaner, B., 99–52–64 Ave., Forest Hills, L. I., N. Y.
Knox, W. G., 207 Parkside Ave., Pittsburgh, 16, Pa.
Kramer, A. S., 377 S. Second St., Lindenhurst, L. I., N. Y.
Kurtz, M., 2 Main Ave., Passaic, N. J.
Laird, E. R., 1146 Richmond St., London, Ont., Canada
Lawrenz, F. W., 2047 Boyd St., Indianapolis, Ind.
Ledbetter, J. B., 3148 Bracken Woods Lane, Cincinnati, 11, Ohio
Low, A. R., Clinton, Ont., Canada
Mackrill, D., Electrical Dept., See Royal Naval Dockyard, Gibraltar

*(Continued on page 48A)*

YOURS .. FOR THE ASKING

Available from local dealers or by writing factory direct.

# UNIVERSAL STROBOSCOPE

This handy phonograph turntable speed indicator, complete with instructive folder, is now available gratis to all phonograph and recorder owners through their local dealers and jobbers. As a recorder aid the Universal Stroboscope will assist in maintaining pre-war quality of recording and reproducing equipment in true pitch and tempo.

Universal Microphone Co., pioneer manufacturers of microphones and home recording components as well as Professional Recording Studio Equipment, takes this means of rendering a service to the owners of phonograph and recording equipment. After victory is ours—dealer shelves will again stock the many new Universal recording components you have been waiting for.

UNIVERSAL MICROPHONE CO.
INGLEWOOD, CALIFORNIA

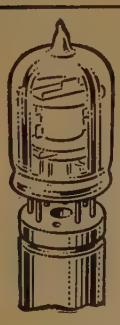
# TUBES GET THE MOST UNEXPECTED ABUSE

Signal Corps tests for Electronic Tubes are exacting . . . and rightly so. For tubes to be totally satisfactory for civilian or military use, they must be built to operate under the most severe and unusual conditions. That is why "vibration testing" was a routine procedure at TUNG-SOL long before the war.

TUNG-SOL research engineers are continuously working to find "weak points" and developing ways and means of overcoming them. With the advent of the glass base tubes for instance, the cause of base fractures was discovered and a production procedure was developed to eliminate it.

Manufacturers and users of Electronic Equipment will find every tube in the TUNG-SOL line a tube of proven merit.

Why not have TUNG-SOL engineers think and work along with you while you are planning your new developments?



## THE TUNG-SOL WAY

**OF COOLING TUBES PREVENTS BREAKAGE OF GLASS BASES..**

While a tube is cooling, during manufacture, air is blown against the center of the glass base through a hole in the holder thus cooling the base from the center out while natural cooling takes place from the edges in. This uniform cooling relieves internal stresses in the glass, a cause of breakage.

# TUNG-SOL

*vibration-tested*

## ELECTRONIC TUBES

ARMY E NAVY

**TUNG-SOL LAMP WORKS INC., NEWARK 4, NEW JERSEY**

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*(Continued on page 60A)*


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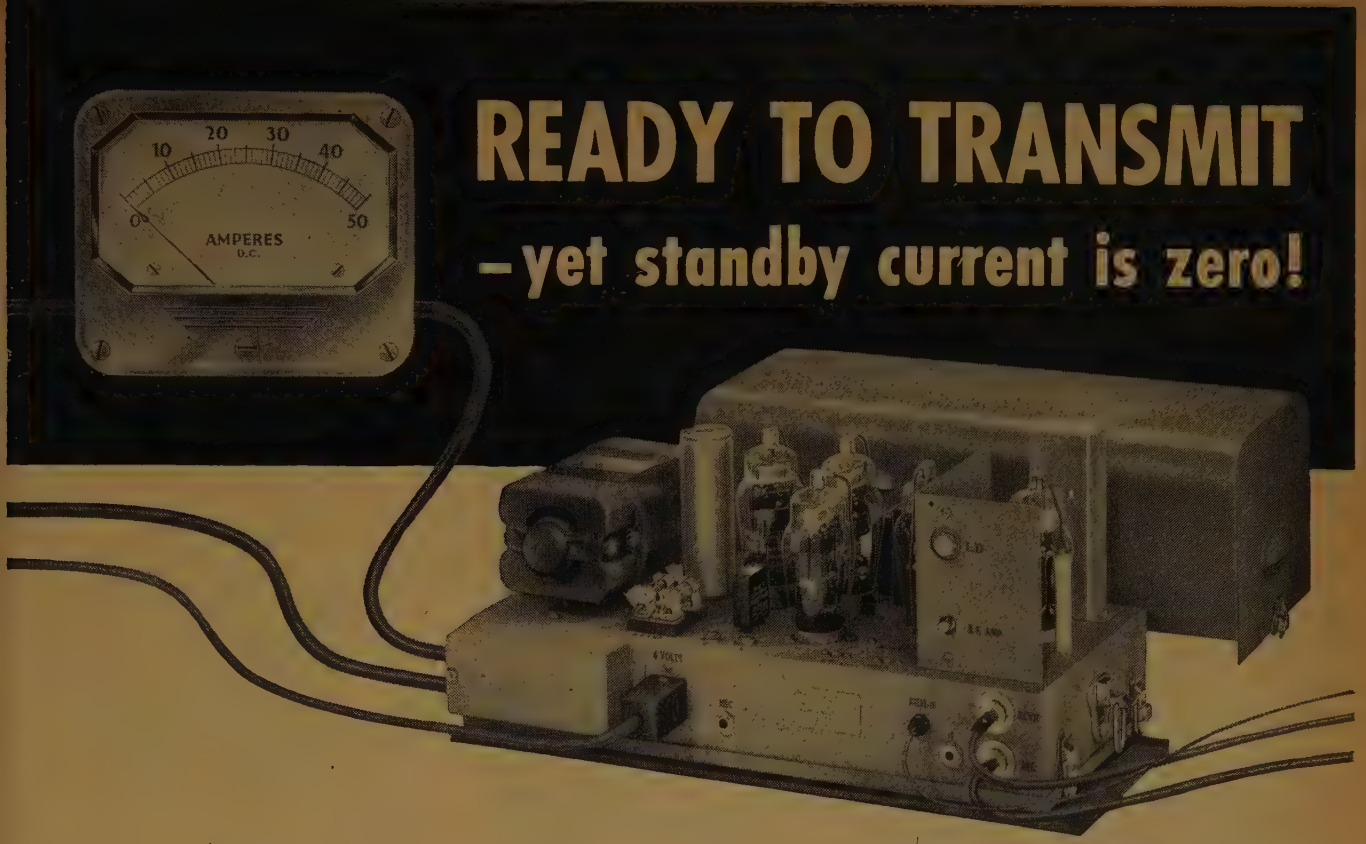


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*(Continued on page 68A)*

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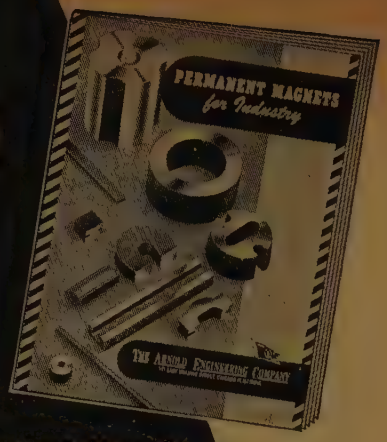


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*(Continued from page 60A)*

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Bonzo, Herberto M., Buenos Aires, Argentina
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Kowalesky, Raymond J., Tower City, Pa.
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Limekiller, Andrew H., New York, N. Y.
Lockard, Ralph E., Jr., Los Angeles, Calif.
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McNabb, William, Harvey, Ill.
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## SECTION MEETINGS

ATLANTA

"A Discussion of Frequency Modulation," by W. R. David, General Electric Company; May 26, 1944.

"A Microwave Demonstration," by M. A. Honnell, Georgia Institute of Technology; June 23, 1944.

BUENOS AIRES

Half-Yearly Dinner of Section Members; August 4, 1944.

Visit to *Radio El Mundo* Studios; August 4, 1944.

CINCINNATI

"Ultra-High-Frequency Measurements," by E. D. Cook, General Electric Company; May 10, 1944.

Discussion of Institute Affairs, by H. M. Turner, President, The Institute of Radio Engineers; June 19, 1944.

Motion Pictures, "The Formica Story" and "The Canadian Rockies"; June 19, 1944.

CONNECTICUT VALLEY

"Canadian Radio Broadcasting," by Armand Trudeau; June 29, 1944.

DALLAS-FORT WORTH

"Discussion and Demonstration of a Coupled-Circuit Frequency Modulator," by E. J. O'Brien, Waco Army Air Field; August 10, 1944.

EMPORIUM

"Joint Army-Navy Tube Standardization Program," by J. W. Greer, Navy Department; July 29, 1944.

"Impact of Chemistry on Electronics," by Dr. Warner, International Telephone and Telegraph Company; July 29, 1944.

WILLIAMSPORT

"Standardization of Electronic Components and the Resultant Saving of Manpower and Unnecessary Parts," by G. A. Mundoen, Signal Corps Standards Agency; August 18, 1944.

"Captured Enemy Radio Equipment," by F. S. Barton, British Air Commission; August 18, 1944.

## MEMBERSHIP

**The following indicated admissions and transfers of membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute by not later than October 31, 1944.**

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*(Continued on page 36A)*

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Storck, H. C., 3723 E. Third St., Dayton, 3, Ohio
Wedig, F. L., 1769 Dale Rd., Cincinnati, 29, Ohio
Wissel, F. A., 3444 Oakview Pl., Cincinnati, 9, Ohio
Wright, R. R., Box 65, Blacksburg, Va.

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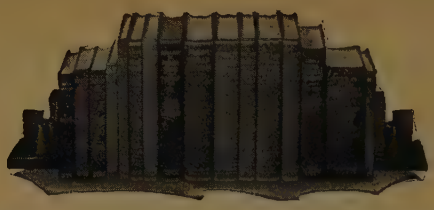

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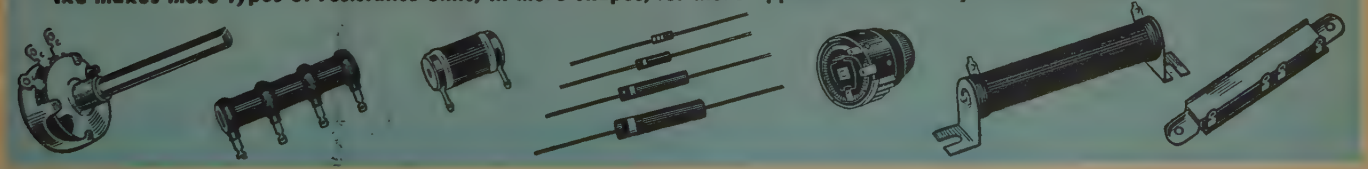

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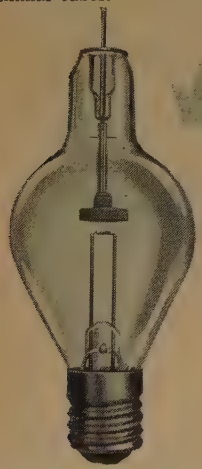

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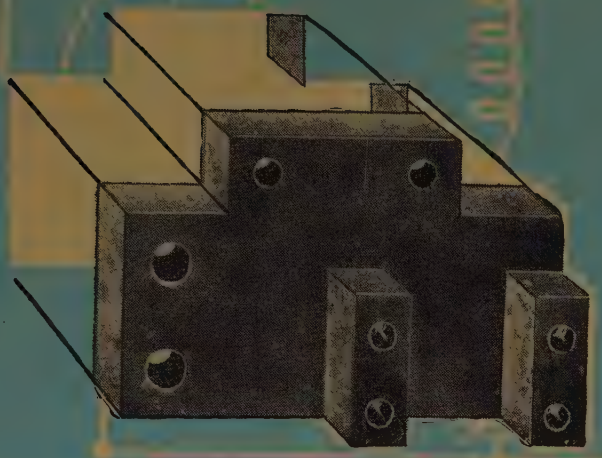

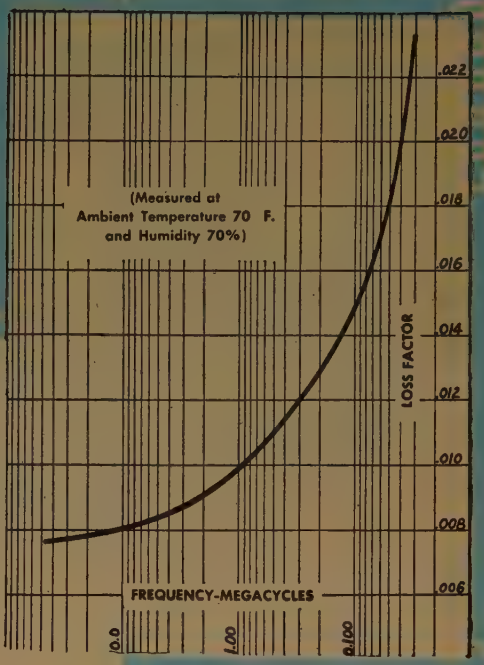


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Some day relatively soon Californians and New Yorkers are going to see a seemingly fantastic spectacle—two sunsets in a single day. It will be achieved by the magic of television, Ralph R. Beal, former research director and now assistant to the vice president in charge of RCA Laboratories, recently reported in discussing postwar possibilities of radio and electronics before members of the San Francisco Engineering Council. Mr. Beal has been an associate member of the Institute since 1915.

"Here in San Francisco," Mr. Beal said, "you will watch Old Sol dip beyond the New Jersey Palisades as a television camera atop Radio City, New York, scans the horizon at sunset. Then three hours later, New Yorkers in the darkness of the evening will catch up with the sun as a television 'eye' in San Francisco sends a panorama of the Golden Gate back across the Continent as the sun ends the day over the Pacific."

Just as radio broadcasting for years has linked the East and the West in sound, Mr. Beal said, so television promises to do it pictorially. He said that by means of automatic, unattended radio relay stations, spaced at intervals across the country, the "East will look in on the West and the West on the East." These radio relay towers, he explained, may be supplemented by specially designed wire circuits or coaxial cables serving "as a sort of optic nerve of the entire nation." He predicted that it will, in effect, be possible to glance across the country in the twinkling of an eye. The big news happenings of the day—parades, Presidential inaugurals, national political conventions, sports classics and the like—will be telecast sky-high over the Great Divide, giving owners of home-television sets grandstand seats, he continued.

Mr. Beal said that the postwar television camera will be so sensitive that it will be able to pick up a bumblebee in flight, or all most anything else visible to the human eye. The camera's eyesight, he said, has been greatly sharpened by recent wartime electronic research.

He disclosed that theater television is "one of the bright prospects of the art," having undergone tests that prove its practicability. He said that just before the war television images were projected on a 15- by 20-foot screen in a Broadway theater with excellent results.

"It creates a fascinating picture," Mr. Beal continued, "to think of theaters throughout the country equipped for large-screen television pictures. The theaters of the nation, connected into television networks, become Broadway play houses with the newest dramatic productions. The theater of the village becomes the Metropolitan Opera House of the nation."

He pointed out also that, while 20,000 or 70,000 people might be packed around a ringside in New York, audiences running into the millions could witness championship bouts or other sports classics in television-equipped theaters. He said it is within reason to estimate that several hundred television

*(Continued on page 48A)*

*Sylvania Radio Tube "Firsts"*

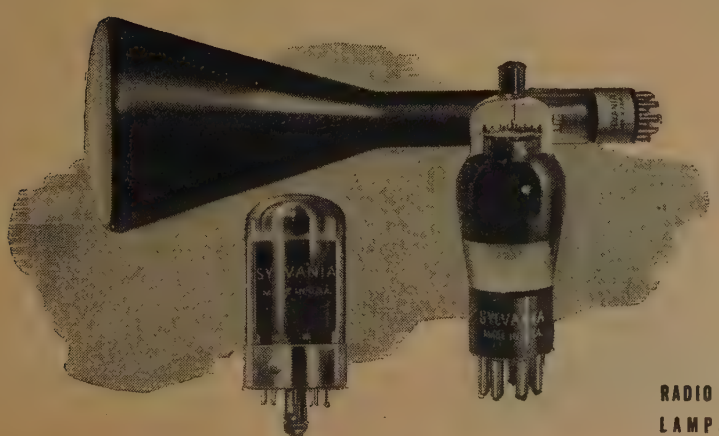
Sylvania was first to introduce a line of 1.4-volt tubes, which made the camera-type portable radio the rage of 1938 and later contributed to our military radio service.

Prior to this Sylvania development, the standard filament voltage for battery receivers was 2.0. This meant that two dry cells had to be connected in series to provide 3 volts. This power was reduced to 2.0 volts by means of a resistor, which dissipated one-third of the expensive voltage.

Sylvania 1.4-volt tubes operated, without resistor, on a single dry cell. Their low filament drain made it possible to build combination receivers that took their power from either a 110-volt power line or a single dry cell.

This development, which is typical of Sylvania's leadership in engineering of economical standardization, went to war in portable radio equipment for close-range military communication. On every front 1.4-volt tubes reduced by half, the battery weight that our boys have to carry.

*Quality that Serves the War Shall Serve the Peace*



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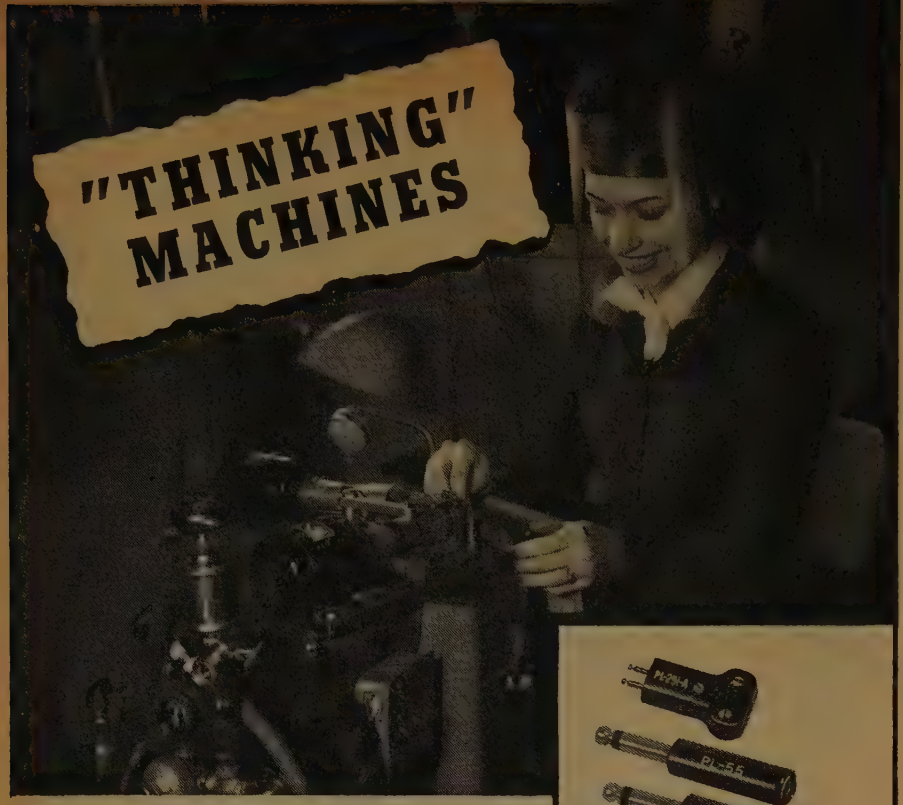


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| 55 | 63 | 77 | 120 | 160 |
| 56 | 64 | 104 | 124 | 291-A |
| 58 | 65 | 108 | 125 | 354 |
| 59 | 67 | 109 | 127 | |
| 60 | 68 | 112 | 149 | |

| PLP | | PLQ | | PLS | |
|---|---|---|---|---|---|
| 56 | 65 | 56 | 65 | 56 | 64 |
| 59 | 67 | 59 | 67 | 59 | 65 |
| 60 | 74 | 60 | 74 | 60 | 74 |
| 61 | 76 | 61 | 76 | 61 | 76 |
| 62 | 77 | 62 | 77 | 62 | 77 |
| 63 | 104 | 63 | 104 | 63 | 104 |
| 64 | | 64 | | | |

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*Announcing & Communication Equipment*


# Future of Radio and Electronics

*(Continued from page 46A)*

stations can be placed in operation in the United States during the first ten years after the war.

Home-television sets, until now confined to 9- by 12-inch screens, will produce much larger and brighter pictures after the war, he predicted. "Before Pearl Harbor experimental home receivers were demonstrated with picture screens 13 inches high and 18 inches wide. Larger pictures up to 18 by 24 inches were produced experimentally. In the postwar world, ingenuity in design and production will bring the television receiver within the range of the average pocketbook."

Discussing scientific progress in harnessing ultrashort wavelengths, he said that frequency modulation, popularly called "FM," offers great promise in bringing new realism and tonal quality into sound broadcasting. He pointed out that the standards established for the transmission of sound by FM stations make possible the true transmission of all sounds within the frequency range of the human ear.

Mr. Beal described the electron tube as the "heart of electronics," and said that its uses are no longer restricted to radio—any more than radio is confined to sending and receiving wireless messages. He listed the electron microscope, radiothermics, and facsimile broadcasting as important developments in electronic art, but declared there were many others secretly helping in the war.

The electron microscope, capable of magnifications up to 100,000 diameters, has a vital wartime role, he asserted. It removes the guesswork from science, exposing forms and elements heretofore beyond the range of human vision. With it, Mr. Beal said, a tuberculosis germ assumes the size of an elephant's footprint; a blood corpuscle becomes as large as a two-foot sofa pillow; and a needle can be magnified to surpass the Washington Monument in bulk. An attachment, known as a "diffraction" camera, has been added to the electron microscope, and it actually ascertains atomic design of infinitesimal objects.

The latter development, he stated, inspired research workers to design an instrument that identifies chemical elements in ultramicroscopic particles of matter. This microanalyzer, whose inventor is Dr. James Hillier, has been used successfully in determining the chemical content of bacterium or virus. It performs its job within a few minutes.

Mr. Beal added that radiothermics, or radio heat, is finding many wartime applications. He pictured its possibilities as running the gamut of heat from cooking to heating homes to making plastics. It has been of invaluable importance in speeding war production of laminated airplane propellers, and other aircraft parts, drying textiles and tempering metal.

"Thus," he concluded, "you see that the magic of radio, which has made New York the communications center of the world, is no longer confined to dots and dashes, or to voices, music and pictures. Radio is a science of unpredictable possibilities that stagger the imagination."

# Specify C. T. C.

CRYSTALS

I-F TRANSFORMERS

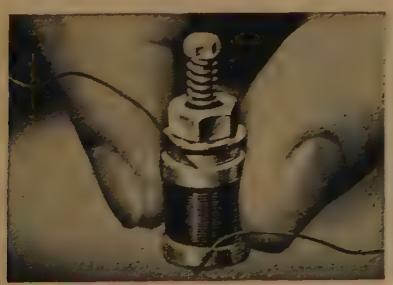
TURRET TERMINAL LUGS

SPLIT LUGS

DOUBLE END TERMINAL LUGS

## C. T. C. CRYSTALS

Accurate cutting of each slice — thanks to X-RAY ORIENTATION — insures constant frequency over a wide temperature range. Multiple mechanical lapping operations; dimensioning by edge lapping and finishing to final frequency by etching, are other important steps in the manufacture of C.T.C. Crystals that guarantee high activity and constant frequency throughout their entire life.



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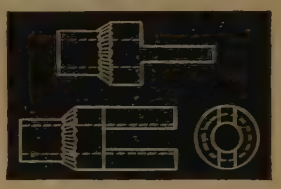
Just swage these heavily silver plated Turret Terminal Lugs to the board and in a jiffy you have a good, firm turret terminal. Quick soldering, too. Sufficient metal is used in the Lugs to give them strength but not enough to draw heat thus increasing soldering time.

C. T. C. Turret Terminal Lugs are stocked to meet 1/32", 2/32", 3/32", 4/32", 6/32", and 8/32" board thicknesses.

## C. T. C. SPLIT LUGS

A .050 hole through the shaft permits wiring to these Split Lugs from either top or bottom without drilling or cutting. Just swage them to the board, then wire. Made of brass, heavily silver plated, C. T. C. Split Lugs are available in two sizes to fit 3/32" and 5/32" boards.



## DOUBLE END TERMINAL LUGS

Use these Double End Terminal Lugs when you need terminal posts on both sides of the board. Like C.T.C. Turret Terminal and Split Lugs, C.T.C. Double End Lugs simply swage to the terminal board — provide twin terminal posts which may be wired from top and bottom. Heavily silver plated brass. Stocked to fit 3/32" terminal boards.

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## SECTION MEETINGS

### Buenos Aires

"The Knowledge of Science," by E. E. Galloni, University of Buenos Aires; July 7, 1944.

"Stability of Electronic Oscillators," by R. P. McLoughlin, RCA Victor Argentina; July 21, 1944.

"Voltage and Current Regulators," by L. Koros, RCA Victor Argentina; August 18, 1944.

### Buffalo-Niagara

"Electronics In Flight Research," by H. Brundige, Bell Aircraft Corporation; September 20, 1944

### Chicago

"Electronic Equipment in Geophysical Prospecting," by S. W. Wilcox, Seismograph Service Corporation; September 15, 1944.

"Electronics Aids the Psychiatrist," W. S. McCulloch, University of Illinois; September 15, 1944.

### Connecticut Valley

"Methods and Equipment Used in Airline Avigation and Communication," by B. E. Montgomery and Robert Dawson, United Air Lines; September 21, 1944.

### Dallas-Fort Worth

"Radio-Field-Intensity Measurements in Proving Antenna Patterns," by B. B. Honeycutt, Station KRLD; September 14, 1944.

### Dayton

"Ground Communication Equipment," by R. B. Colton, Signal Corps United States Army; September 28, 1944.

### Detroit

"The Communication Engineer Looks into the Future," by E. C. Balch, Michigan Bell Telephone Company; September 21, 1944.

### Emporium

"The Application of Compensation Circuits to Electronic Voltage Regulators," by L. I. Knudson, Sylvania Electric Products; September 27, 1944.

Motion Picture, "Your Ship In Action"; September 27, 1944.

### Kansas City

"Coaxial Transmission Lines and Wave Guides," by Harner Selvidge, Fournier Institute of the Arthur J. Schmitt Foundation; September 19, 1944.

### New York

"The Use of Radio Facilities by the Office of War Information," by J. O. Weldon, Office of War Information; September 6, 1944.

"Ultra-Short-Wave Receiver for the Cape-Charles—Norfolk Multiplex System," by D. M. Black, G. Rodwin, and W. T. Wintringham, Bell Telephone Laboratories, Inc.; September 13, 1944.

"Cape Charles—Norfolk Ultra-Short-Wave Multiplex System," by N. F. Schlaak and A. C. Dickieson, Bell Telephone Laboratories, Inc.; September 13, 1944.

"Ultra-Short-Wave Multiplex," by C. R. Burrows and Alfred Decino, Bell Telephone Laboratories, Inc.; September 13, 1944.

"Ultra-Short-Wave Transmitter for the Cape Charles—Norfolk Multiplex System," by R. J. Kircher and R. W. Friis, Bell Telephone Laboratories, Inc.; September 13, 1944.

### Twin Cities

"Postwar Industrial Design in Electronics," by H. W. Darr, The Maico Company, Inc.; September 19, 1944.

### Washington

"What Is To Be Said Now of Facsimile?," by I. S. Coggeshall and J. H. Hackenberg, Western Union Telegraph Company; September 11, 1944.

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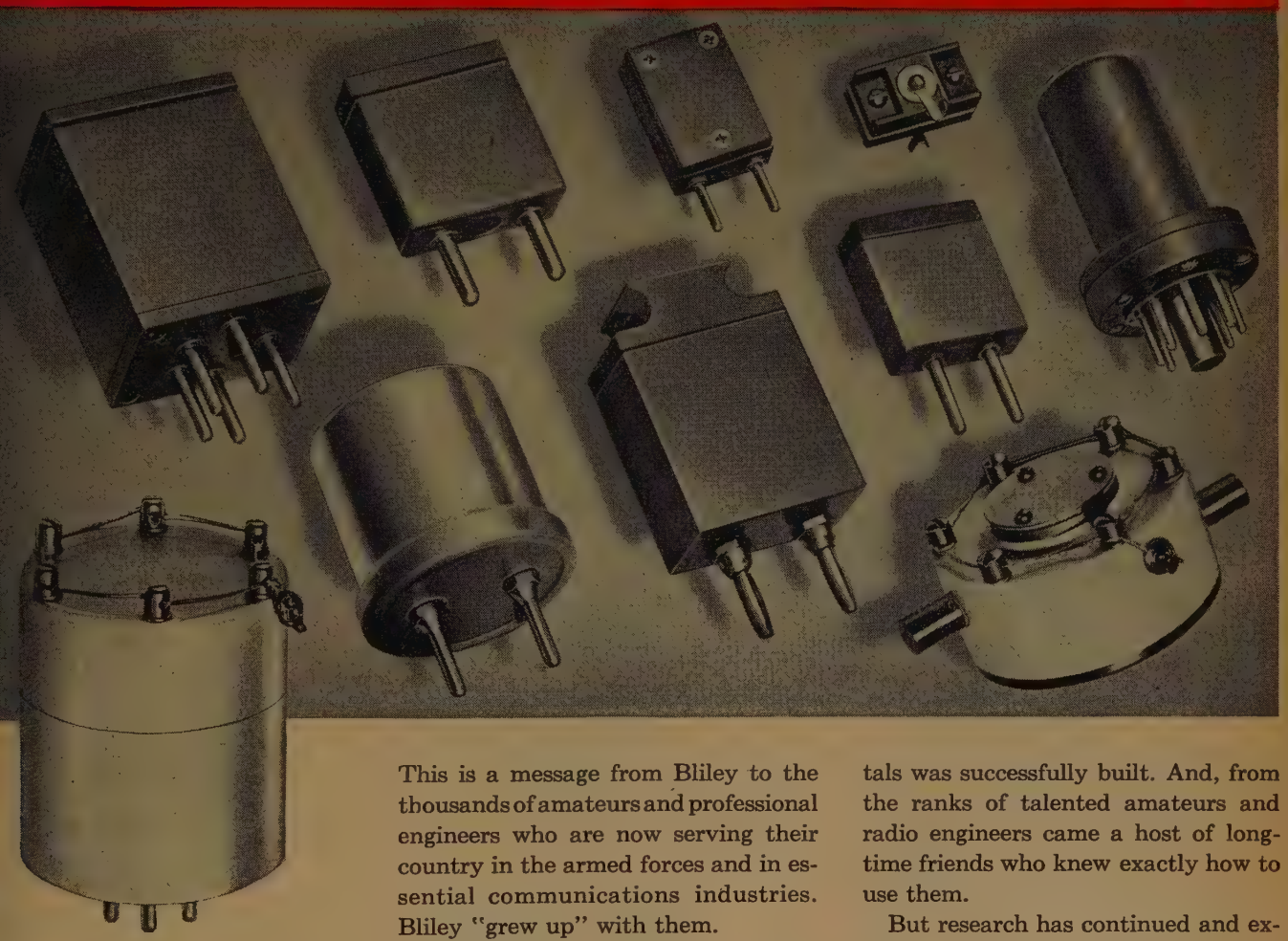

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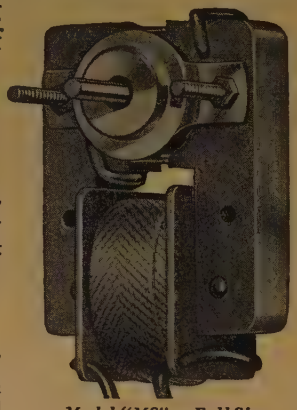

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Christaldi, P. S., 132 Squire Hill Rd., Upper Montclair, N. J.
Corbett, C. W., 333 E. 53 St., New York, N. Y.
DeVore, L. T., 1245 Arbor Ave., Dayton, Ohio
Donovan, W. E., 40 E. 49 St., New York, N. Y.
Everest, F. A., 1011 Encino Row, Coronado, Calif.
Greig, D. D., 106-15 Queens Blvd., Forest Hills, L. I., N. Y.
Gubin S., 4417 Pine St., Philadelphia, Pa.
MacLean, K. G., R.C.A. Laboratories, Riverhead, L. I., N. Y.
Noble, D. E., 165 Garfield Ave., Elmhurst, Ill.
Ostlund, E. M., 194 Grove St., Montclair, N. J.
Ramo, S., General Electric Company, Schenectady, N. Y.
Scheer, G. H., Jr., R.F.D. 5, Box 379, Dayton, Ohio
Wentz, J., 180 Varick St., New York, N. Y
Wright, J. W., 122 Webster Ave., Manhasset, L. I., N. Y.

### Admission to Senior Member

Duffendack, O. S., North American Philips Company, Richmond Hill, Irvington-on-the-Hudson, N. Y.
Sherman, V. W., Federal Telephone and Radio Corporation, 200 Mt. Pleasant Ave., Newark, N. J.

### Transfer to Member

Campbell, M. E., A.P.O. 518, c/o Postmaster, New York, N. Y.
Deerhake, F. M., 600 Oakwood St., Fayetteville,
Edwards, H. H., 186-21—122 Ave., St. Albans, L. I., N. Y.
Ellithorn, H. E., 417 Parkovash Ave., South Bend, Ind.
Espy, W. D., 362—30 Street Dr., S. E., Cedar Rapids, Iowa
Fernandez, M., 20 Ferrying Group, A.T.C., Municipal Airport, Nashville, Tenn.
Fiedler, L., 53 Rosedale, Hamburg, N. Y.
Gorman, D. P., E. 521 Sharp Ave., Spokane, Wash.
Graf, A. W., 4 Midway Ct., Hammond, Ind.
Hirsch, O. C., 324 Broadway, Cape Girardeau, Mo.
McCartney, H. S., 625 Second Ave., S., Minneapolis 2, Minn.
Sharp, W. O., Bell Telephone Laboratories, 395 Hudson St., New York 14, N. Y.
Sokoloff, P. W., 68-19 Burns St., Forest Hills, L. I., N. Y.
Squires, E. G., 319 E. Jefferson Ave., Wheaton, Ill.
Stockman, H., Cruft Laboratory, Harvard University, Cambridge 38, Mass.
Thomas, H. P., 202 Huntleigh Ave., Fayetteville, N. Y.
Wang, T. S., 726 Cooper St., Camden, N. J.
Williamson, R. H., 161 E. Onondaga St., Syracuse 2, N. Y.

### Admission to Member

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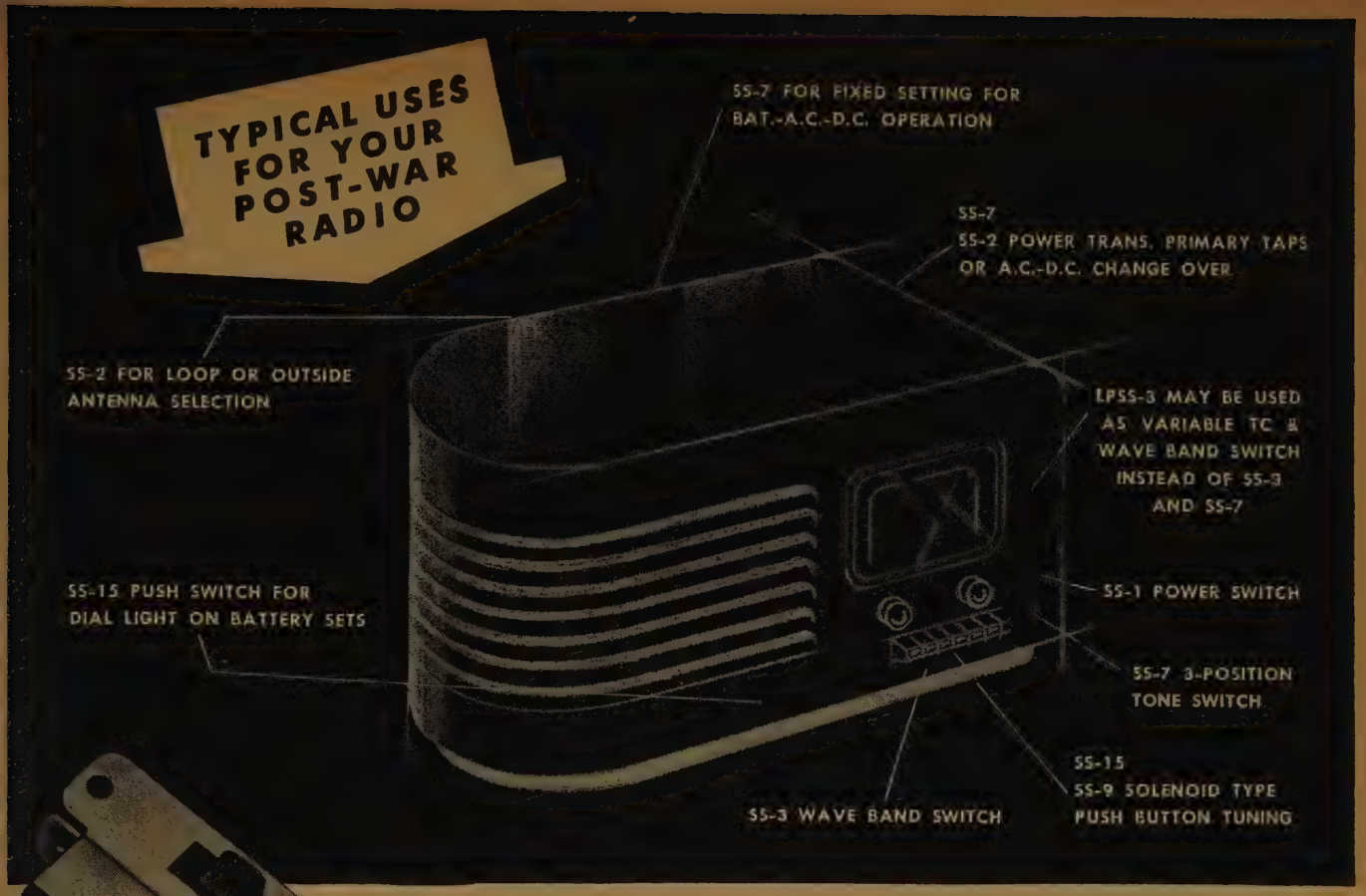
Davis, F. M., 1429 Wildwood Dr., N. E., Cedar Rapids, Iowa
Feldt, R., 875 W. 181 St., New York 33, N. Y.
Hackett, A. H., Apartado 1226, Telephone Company, Caracas, Venezuela
Laning, W. A., 70 Glen Ridge Ave., Glen Ridge, N. J.
Norman, S. W., 300 Buxton Rd., Falls Church, Va.
Warner, A. W., Jr., Bell Telephone Laboratories, Murray Hill, N. J.
Weid, A. C., Airborne Instruments Laboratory, 150 Old Country Rd., Mineola, L. I., N. Y.
Weissman, S., 321 W. Norman Ave., Dayton 5, Ohio

*(Continued on page 40A)*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5S-7
5S-2 POWER TRANS. PRIMARY TAPS OR A.C.-D.C. CHANGE OVER
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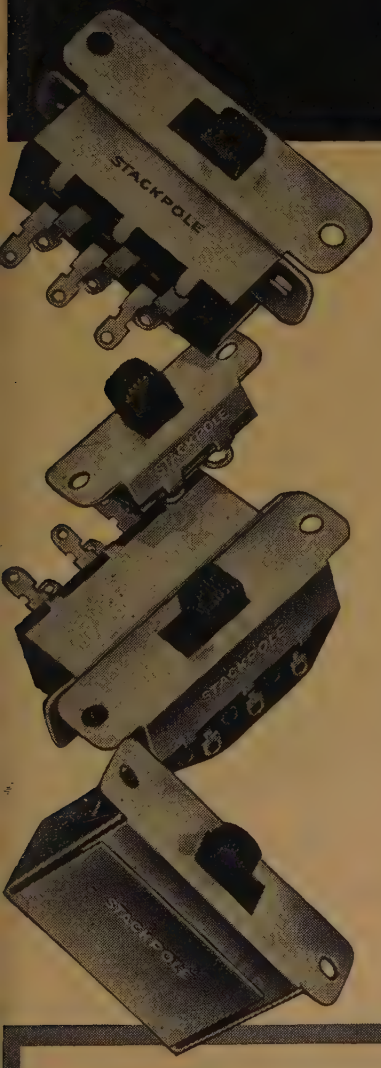
5S-15 PUSH SWITCH FOR DIAL LIGHT ON BATTERY SETS
5S-1 POWER SWITCH
5S-7 3-POSITION TONE SWITCH
5S-15
5S-9 SOLENOID TYPE PUSH BUTTON TUNING
5S-3 WAVE BAND SWITCH

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*(Continued from page 38A)*

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Anderson, C. K., 2 Prescott St., Cambridge 38, Mass.
Askitoglou, T. J., Eglence Sokak No. 3, Arnavutkoy, Istanbul, Turkey
Bahlay, A., 442 Harbor Hills, Lomita 4, Calif.
Balsam, S., 1517 Charlotte St., New York 60, N. Y.
Bartley, G. A., No. 3 Wireless School, Winnipeg, Manit., Canada
Baxter, R. F., Lunenburg, Ont., Canada.
Bedford, C. F., Sixth Ave., McKellar, Westboro, Ont., Canada.
Benton, A., 1841 Glendon Ave., Los Angeles 25, Calif.
Baumeister, E. M., Co. O., AA-3, AAATC, Camp Haan, Calif.
Berg, L. W., 89-11—34 Ave., Jackson Heights, L. I., N. Y.
Beverly, N. E., Sprague Electric Company, North Adams, Mass.
Blanchard, J. W., 350 E. 86 St., New York 28, N. Y.
Bodin, J. A., Box 2175, Houston, Tex.
Brodribb, M. I., Flat 41, 453 St. Kilda Rd., Melbourne, Victoria, Australia
Carson, G. W., 7918 Marquette Ave., Chicago 17, Ill.
Chamberlain, R. D., Box 265, Houma, La.
Chatterton, E. G., 112 Nimitz Dr. (Overlook Homes) Dayton 3, Ohio
Cherry, L. B., 2121 Washington La., Philadelphia 38, Pa.
Clair, F. F., 863 County Line Rd., Copeland Park, Newport News, Va.
Clarke, W. L., Instructors Co., Bks. 10, NATTC, Ward Island, Corpus Christi, Tex.
Clipstone, A. E., 14 Epperstone Rd., West Bridgford, Nottingham, England
Corte, L. P., "Roseneath" 22 Abbotts Rd., Aylesbury, Bucks, England.
Coulter, W. H., c/o Press Wireless Inc., Hicksville, L. I., N. Y.
Demers, R. H., R.C.A.F. Station, Gaspé, Que., Canada
Douglass, J. D., 21265 Kenwood Ave., Rocky River, Ohio
Filman, N. J., 864 McEachran Ave., Outremont, Montreal 8, Que., Canada
Fisher, F. J., 738 Colborne St., London, Ont., Canada
Fogg, C. P., 5 Malvern House, Abbey Rd., Great Malvern, Worcestershire, England
Forrest, W. C., Poynette, Wis.
Fountain, L. R., 15 Cortland, Springfield, Mass.
Ganguly, S. K., 19 Chakrabere Rd., S., Bhawanipore, Calcutta, India
Gilbert, M., Canadian Broadcasting Corporation, Chateau Laurier Hotel, Ottawa, Ont., Canada
Gilbert, R. L., 522 Piccadilly St., London, Ont., Canada.
Goble, R. W., 1360 Speer Blvd., Box 1500, Denver 1, Colo.
Gookin, K. A., Naval Research Laboratory, Bldg. 33A, Anacostia Station, D. C.
Gore, E. M., 3303 Porter St., N. W., Washington, D. C.
Gotch, J. X., 123 S. Monroe St., Streator, Ill.
Greenberg, M. L., 3322 Leslie, Detroit 6, Mich.
Gross, H. R., 1 Miller St., Caldwell, N. J.
Hamilton, J. R., 317 E. 29 St., Brooklyn 26, N. Y.
Himmel, H., 817 West End Ave., New York 25, N. Y.
Himmer, F., Jr., 6703 Cresheim Rd., Philadelphia 14, Pa.
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*(Continued on page 46A)*

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| 40A40-2 | S-0215 | .003 | 600 | 3/16 | 17/32 |
| 40A40-3 | S-0221 | .01 | 150 | 1/4 | 21/32 |
| 40A40-4 | S-0224 | .02 | 600 | 1/4 | 21/32 |
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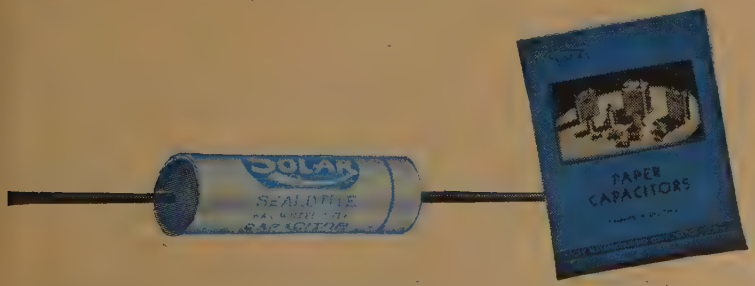


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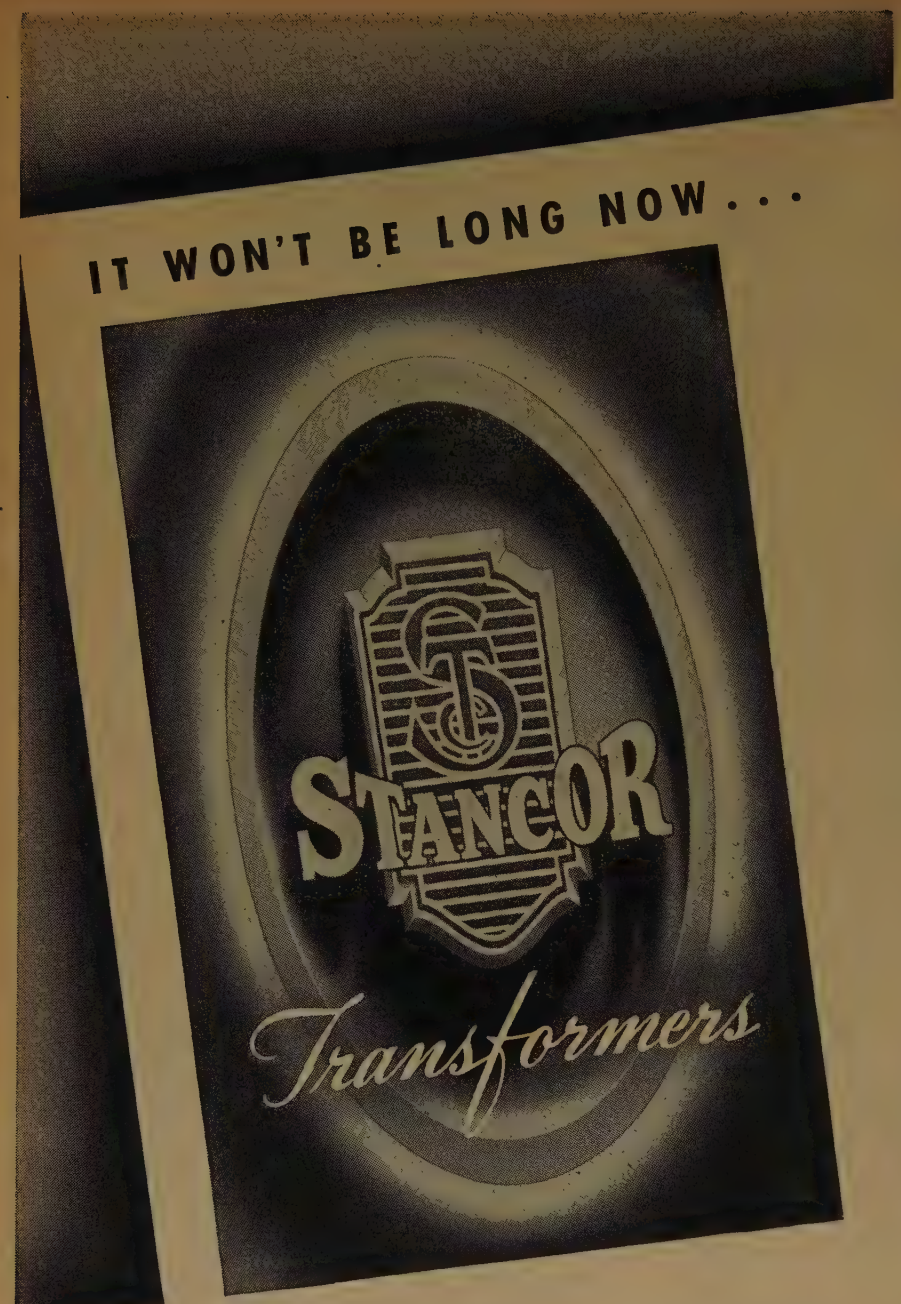


. . . and Stancor will "step ahead" with postwar plans that not only will include units for most every communication and electronic apparatus, but will have inherent in those transformers, design technique which our extraordinary war production has demanded . . . Yes, Stancor is worth waiting for. So, before you specify —consult "Stancor for Postwar."

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Mackenzie, N. F., Electronics Division, Aircraft Radio Laboratory, Wright Field, Dayton, Ohio
Mathur, K. B., ATS Todhpur Railway, Todhpur, India
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Payne, J. E., Jr., 16 LawrenceCir., Portsmouth, Va.
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Ramsay, R. D., 14818 Forrer St., Detroit 27, Mich.
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Spears, R. W., 126 Commonwealth, Boston, Mass.
Stafford, C. B., A.P.O. 650, c/o Postmaster, New York, N. Y.

*(Continued on page 62A)*

No wonder American industrialists are dizzy! – Columnists, commentators, conferences and a host of critics on the sidelines advising business to "Go ahead" — to "Hold back" — to "Stand still."

**Red lights today, green lights tomorrow.**

Through the maze of conflicting regulations, press releases, industry bulletins, it is safe to predict, however, that civilian production will resume shortly. But we must win the war first.

We at G. I., realizing that wars always end more suddenly than they begin, decided long ago on a post war planning schedule. It may help to clarify your problem to know that we will be under way immediately when Uncle Sam issues the go-ahead signal.

Our products comprise new and improved components in the electronic and radio fields — variable condensers, automatic tuning mechanisms, record changers and new items developed and perfected from the research of our wartime experience.

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# Television has New and Potent Industrial Applications

*Ralph R. Beal of RCA Tells Detroit Engineering Society Radio Sight Can Be "Eyes" for Plant Control to Speed Production and Assure Optimum Results in Manufacturing*

Disclosure of potentialitie of television as a new and effective aid to industry after the war enlivened a meeting here tonight at which Ralph R. Beal, Assistant to the Vice President in Charge of RCA Laboratories, told members of the Engineering Society of Detroit of the imminent expansion of this promising art and science.

Declaring it "indeed appropriate" to make his revelations in "one of the world's most forward-looking and busiest industrial communities," Mr. Beal, who arrived today from New York, envisaged television as the coming "eyes" of factories, the "means of coordinating activities in giant manufacturing plants, such as those in Detroit, and the means also of peering into places and situations that might be inaccessible or extremely hazardous to man."

Mr. Beal said that those like himself who are close to television foresee the day after fighting ceases when this type of television application may be in "wide" use.

"We know now," the research engineer declared, "how it can be used to extend the eyesight of the plant manager to critical operations that ordinarily would require much time and effort to reach for personal inspection or which might even be inaccessible—how television can aid immeasurably in plant control.

"Television cameras at strategic points can be connected by wire to receivers where production experts, foremen and supervisors can follow the flow of fabricated or raw materials and watch the progress of the work. Such setups will be particularly valuable in mass production assembly lines, and they may be extended to include loading platforms and shipping rooms."

According to Mr. Beal, television cameras may be used in connection with chemical reaction chambers, making visible to the operator without personal risk the chain of events occurring in complicated chemical production units, and thus enable him to control the process with optimum results. He said specially-built cameras may be used in furnaces to observe steps in the formation of alloys, and others may solve vital problems of analysis in important industrial processes.

"In addition," Mr. Beal declared, "television equipment may facilitate port move-

*(Continued on page 66A)*

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This release may come at any moment. Be sure that your needs are listed at the top of our peace-time back-log. The planning you do now will speed your own reconversion to the new high standards of the future.

Andrew engineers will gladly apply their years of skilled experience to the solution of your special problems in the field of directional antenna equipment:

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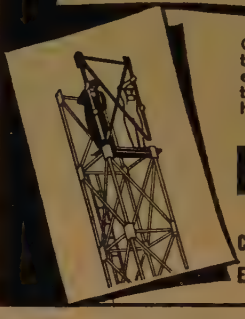

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Instead of stacking tissue-thin laminations by hand, you can now get pre-assembled, two-piece HIPERSIL cores, ready for quick, easy assembly. Because there are just TWO pieces to handle per loop, valuable man-hours are saved in production—faults in assembly are prevented. HIPERSIL cores are available in a complete range of standard as well as special sizes and forms.

**GET ALL THE FACTS ABOUT HIPERSIL TYPE C CORES** . . . write for copy of HIPERSIL Booklet, B-3223-A. It contains performance facts and application data that will help speed the production of vital Communications Equipment for the Fighting Forces. Address: Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, Dept. 7-N.

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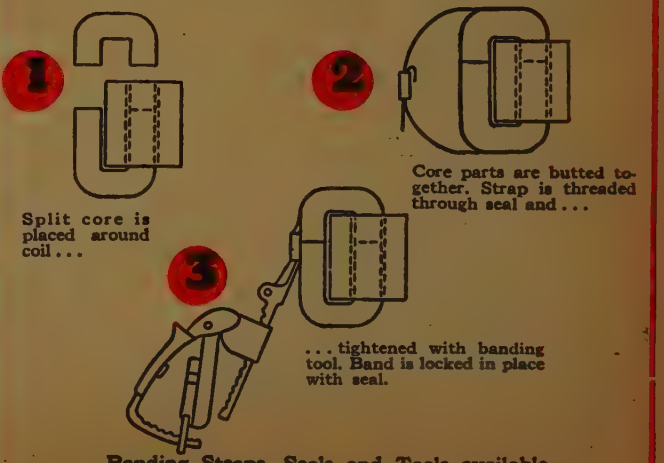
1
Split core is placed around coil . . .
2
Core parts are butted together. Strap is threaded through seal and . . .
3
. . . tightened with banding tool. Band is locked in place with seal.

Banding Straps, Seals and Tools available from Westinghouse. See Page 9 of B-3223-A.

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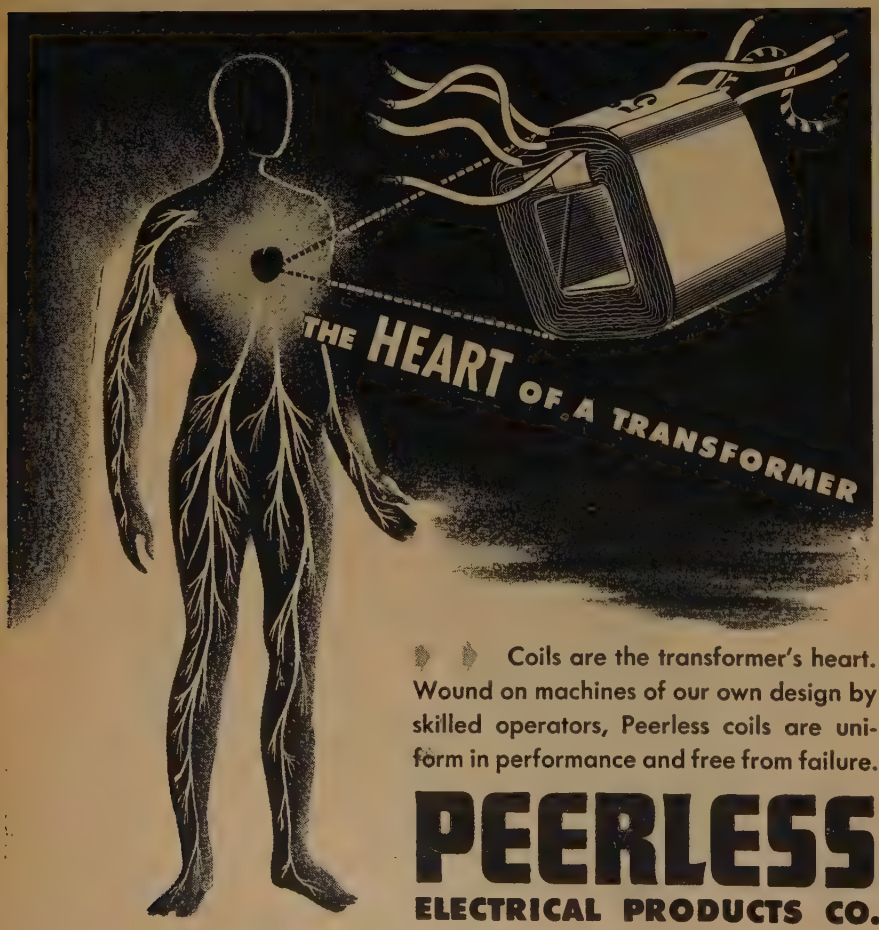


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6920 McKINLEY AVENUE, LOS ANGELES 1, CALIFORNIA


# Television has New and Potent Industrial Applications

*(Continued from page 58A)*

ments of ships. The cameras located fore and aft, and on port and starboard sides of vessels, could lessen the hazards of docking and insure safety in crowded shipping lanes.

"We likewise foresee the use of television in metropolitan traffic control and along congested motor routes. Cameras may be installed permanently at busy inter-sections to flash to traffic headquarters running, up-to-the-minute picture accounts that should greatly aid traffic experts in easing congestion."

Mr. Beal said that it is "reasonable to assume" that television tubes and associated electronic devices together with photo-electric cells, may "facilitate increasingly the development of new industrial processes and methods, seemingly far removed from the usual sphere of radio science."

The ultimate aim in television is to match the perfection of the human eye, Mr. Beal said, and added: "The significance of that is obvious. We hope, in years to come, not only to televise the world's still life and action in three-dimensional views, but to transmit scenes in their exact color." He disclosed that research scientists and engineers of RCA Laboratories have already devoted many years of study and experimentation to color television and believe it to be a definite prospect.

Mr. Beal told his Detroit audience how plans for the post-war manufacture of television equipment and the establishment of television networks were, as war conditions permitted, taking definite shape. He said that once industry converts to peacetime enterprise, his company is prepared to build television home receivers and transmitting equipment of high standard at moderate cost and predicted that an all-American network will, a few years hence, link Detroit and other big cities.

One contribution that automotive engineers can make to television service, Mr. Beal asserted, is the suppression of "man-made static," or electrical interference, caused by automobile ignition systems. Many ignition systems, he explained, are in effect small "transmitters" that send out signals which mar television pictures and accompanying sound. Considerable progress has been made toward solving the problem, he reported.

"Television," Mr. Beal declared, "is here to stay—and to grow—and to multiply. . . . A multitude of hopes and dreams of Americans for an expanded production of the good things of life, greater culture, friendship and understanding, and more enjoyable living are symbolized in the one word—television."

# Guns FOR VICTORY!

Recently the Army-Navy "E" for production excellence was awarded to Allen B. DuMont Laboratories, Inc. In accepting this high honor, Allen B. DuMont said in part:

"Originally the Navy 'E' went to that ship scoring outstanding marksmanship. Today that 'E' again reverts to its original meaning. We of the DuMont organization make *electronic guns*. Each cathode-ray tube contains an electronic gun. We make those guns as accurately as our skill, ingenuity and conscientious inspection can make them. Thus I hope that our 'E' is the direct result of good electronic marksmanship, as reflected by the reports from various battlefronts."

Electronic guns for victory! Such is the DuMont contribution to the war effort, made possible *qualitatively* by years of pioneering experience, and now *quantitatively* as well by a 400% growth in personnel. In four large DuMont plants and in several DuMont laboratories, continuing electronic victories are assured for winning today's war and tomorrow's peace.

## SUBMIT YOUR CATHODE-RAY PROBLEMS . . .

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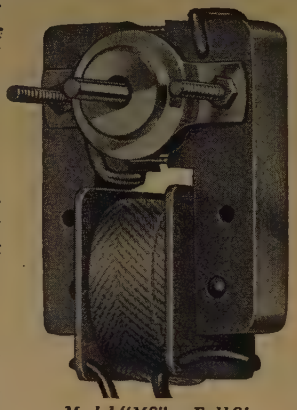

*Model "MS" — Full Size Motor Measures 1¾" x 2 x 3⅛"*

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Our long established standards of precision manufacturing from highest grade materials are strictly adhered to in these models to insure long life without breakdowns.

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## SECTION MEETINGS

BUFFALO-NIAGARA

"Meters for Electronic Measurements," by W. Bergerson, Electrical Instrument Laboratories; October 18, 1944.

CHICAGO

"Scientific Approach to Problems in Industrial Electronics," by J. C. Frommer, Bell and Howell Company; October 20, 1944.

"Unusual Tube Circuits," by E. C. Kent, C. G. Conn, Ltd.; October 20, 1944.

CINCINNATI

"Becoming a Registered Professional Engineer," by Alfred LeFeber, Ohio Society of Professional Engineers; September 19, 1944.

DALLAS-FORT WORTH

"Measurement Scales Used in Communication Engineering," by N. B. Fowler, American Telephone and Telegraph Company; October 6, 1944.

DAYTON

"Industrial Electronics," by E. F. W. Alexanderson, General Electric Company; October 26, 1944.

Movies, "Frequency Modulation," and "Television," General Electric Company; October 26, 1944.

EMPORIUM

"Multiform Process Glass," by George Bair, Corning Glass Works; October 17, 1944.

INDIANAPOLIS

"Development and Operation of the Signal Corps Radio Equipment Type SCR 284," by H. V. Noble, Crosley Radio Corporation; September 22, 1944.

MONTREAL

"What Frequency-Modulation Radio Can Do For Canada," by W. G. Broughton, General Electric Company; October 11, 1944.

NEW YORK

"Program-Transmission Circuits for Frequency-Modulation Broadcast Stations," by E. W. Baker, American Telephone and Telegraph Company; October 4, 1944.

OTTAWA

"What's New in Science and Engineering," by E. S. Lee, General Electric Company; September 21, 1944.

"Frequency Modulation," by W. G. Broughton, General Electric Company; October 10, 1944.

PHILADELPHIA

"Coupled Circuits," by H. M. Turner, President, Institute of Radio Engineers, October 3, 1944.

PORTLAND

"Voltage Regulators," by W. R. Hill, University of Washington, October 13, 1944.

ST. LOUIS

"Wave Guides and Coaxial Transmission Lines," by Harner Selvidge, Fournier Institute, September 21, 1944.

TWIN CITIES

"Frequency Modulation in Practice," by J. D. Klug, KSTP; October 10, 1944.

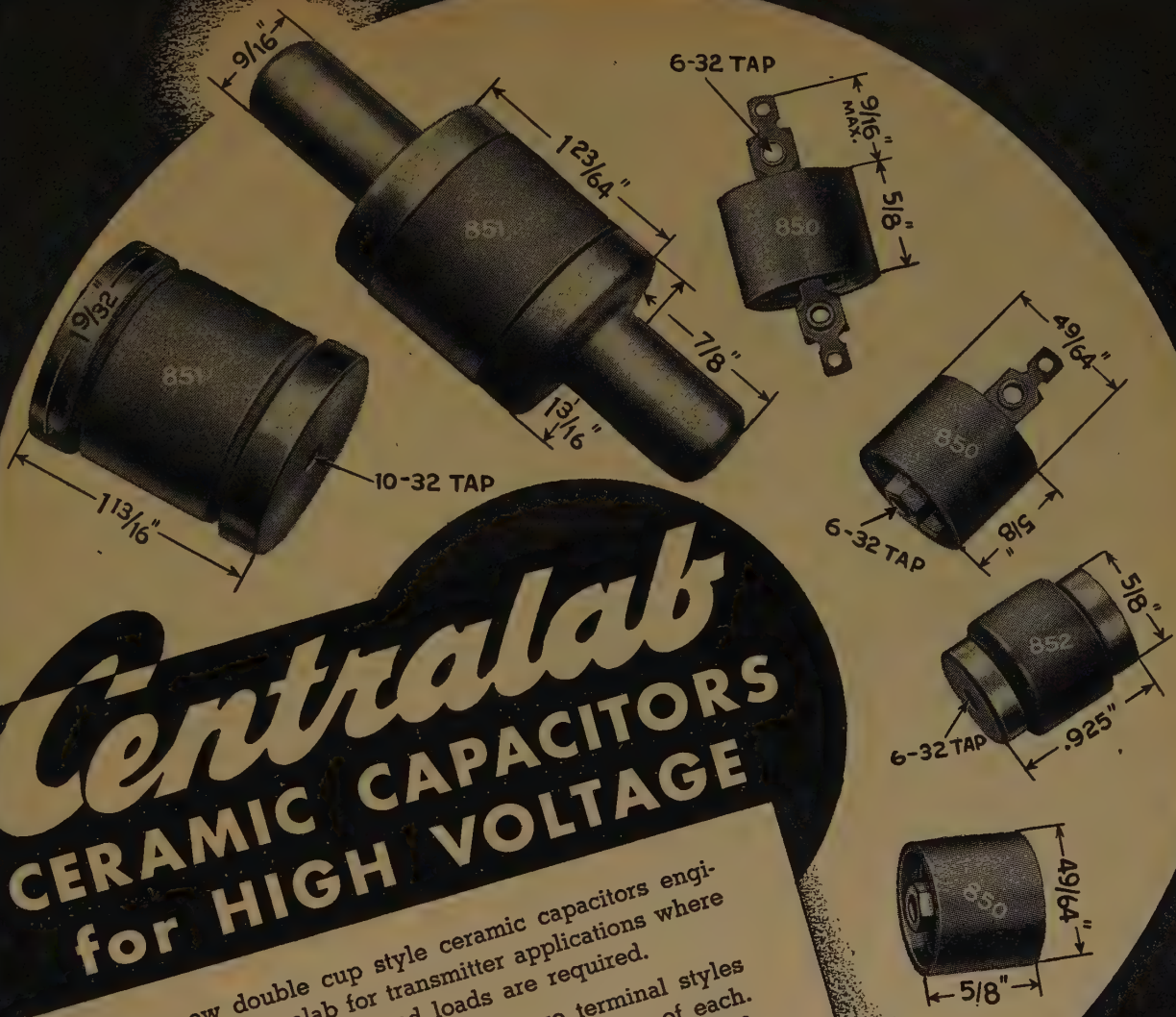
WASHINGTON

"A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver" by G. L. Beers, Radio Corporation of America; October 9, 1944.

WILLIAMSPORT

"Standardization of Radio Tubes," by Jerry Steen, Sylvania Electric Products, Inc.; October 6, 1944.

"Klystron Operation," by A. E. Harrison, Sperry Research Laboratories; October 20, 1944.

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Type 850 currently available with two terminal styles — axial screw type and lug style . . . or one of each. Capacities ranging from 25MMF NPO to 100MMF N750. Working voltage to 10,000 D.C. Type 851 available with two terminal styles as illustrated. Capacities ranging from 25MMF NPO to 200 MMF N750. Working voltage to 20,000 D.C.

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Clapp, R. G., 215 W. Montgomery Ave., Haverford, Pa.
Dunlap, O. E., Jr., 19 Barstow Rd., Great Neck, L. I., N. Y.
Duttera, W. S., 35 Hampton Rd., Lynbrook, L. I., N. Y.
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Glover, R. P., 1024 Superior St., Oak Park, Ill.
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Marble, F. G., 63 Greenhurst Rd., West Hartford 7, Conn.
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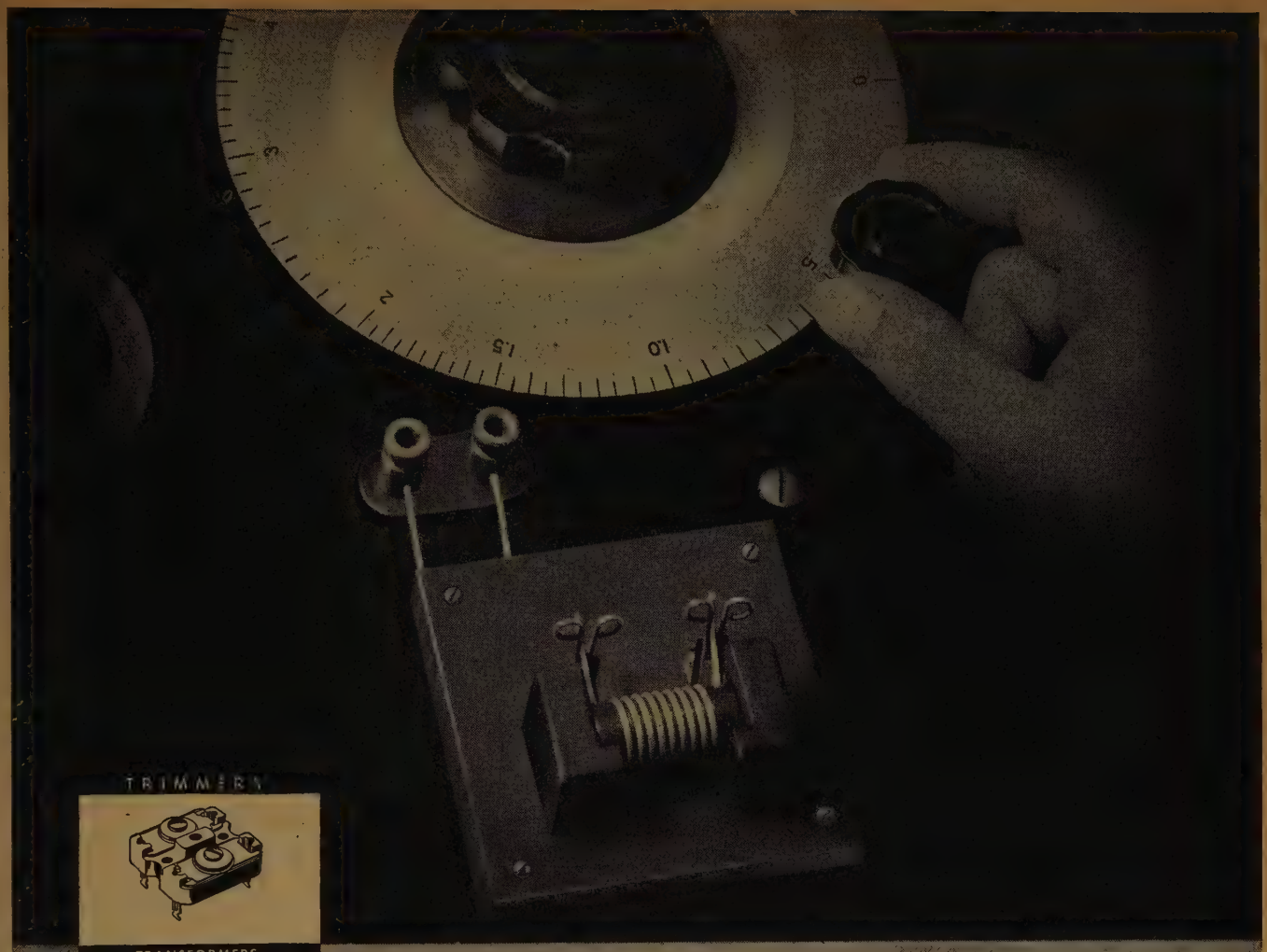




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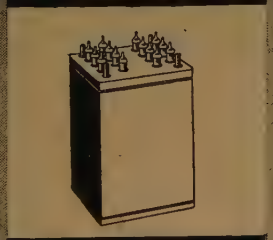

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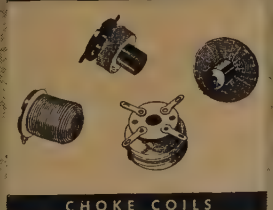

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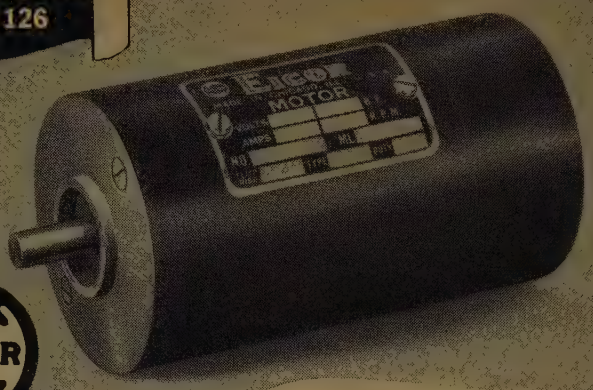

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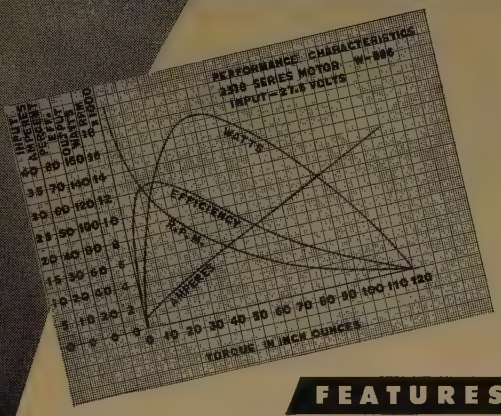
## 1/5 HP at 3800 RPM

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| Low starting current | Completely enclosed |
| High efficiency | Base or flange mounting |
| Low RF interference | Laminated field poles |
| Unidirectional or reversible | Precision ball bearings |
| Armature and field windings varnish impregnated and baked | Segment-built commutator |
| | Permanent end play adjustment |

| 2300 FRAME MOTORS | | 2318 Series | 2310 Shunt |
|---|---|---|---|
| Watts Output, Int. | (max.) | 160 | 50 |
| Torque at 6000 RPM | (in. oz.) | 40 | 10 |
| Torque at 3800 RPM | (in. oz.) | 57 | — |
| Lock Torque | (in. oz.) | 120 | 14 |
| Volts Input | (min.) | 5 | 5 |
| Volts Input | (max.) | 110 | 28 |
| Temperature Rise | (int.) | 50°C | 50°C |
| Diameter | | 2 5/16" | 2 5/16" |
| Length less shaft | | 4 5/32" | 2 3/4" |
| Shaft Dia. | (max.) | .312" | .312" |
| Weight | (lbs.) | 2.4 | 1.5 |

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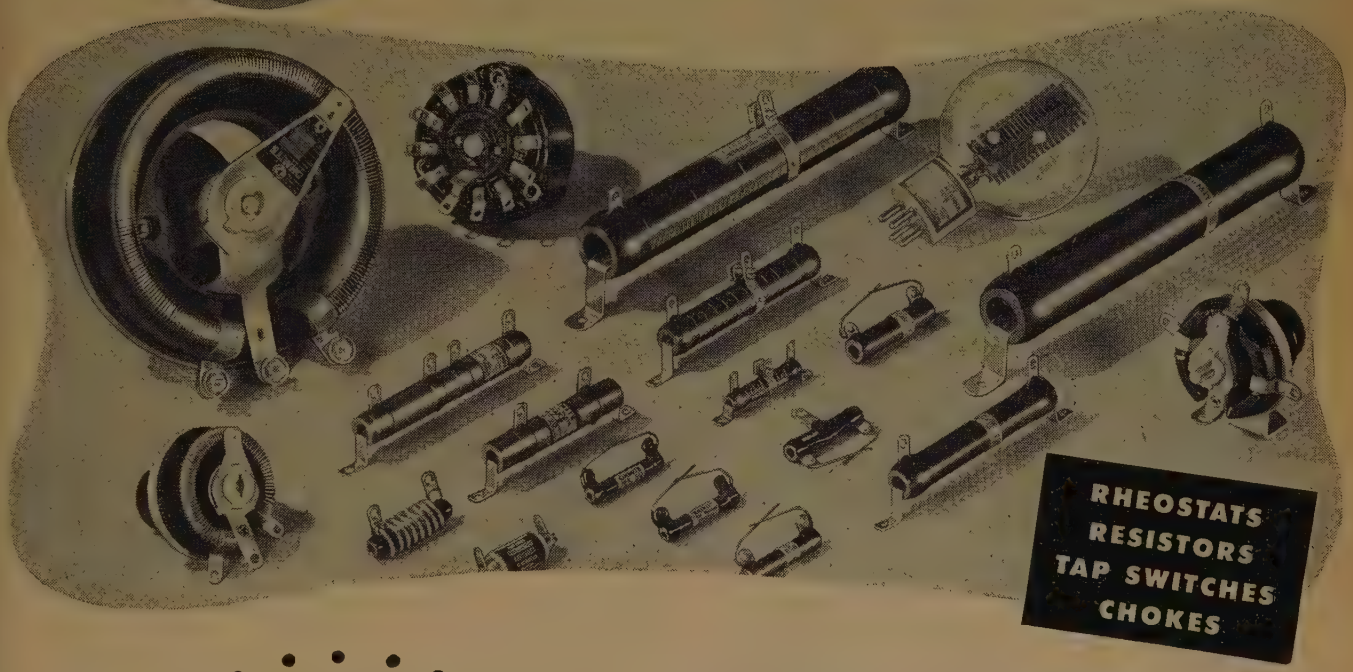


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***Input resistance*** 4.4 megohms on all A.C. ranges. Flat frequency response between 50 cycles and 10,000 cycles.

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Either positive or negative D.C. voltmeter indications instantly by means of reversal switch. Signal tracing type test lead with isolation resistor in probe. Model 645 is an ultra-modern high sensitivity instrument, with all of the famous Jackson features, including exceptional accuracy and simplicity of use.

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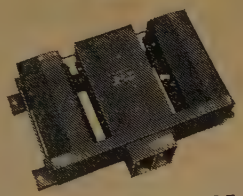

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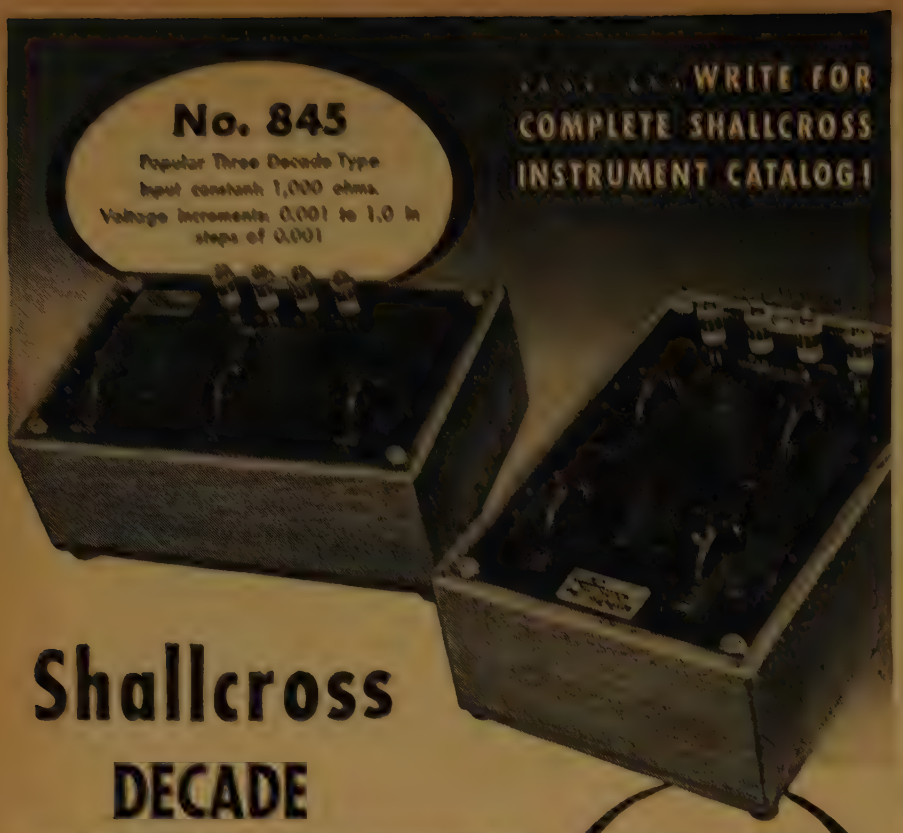
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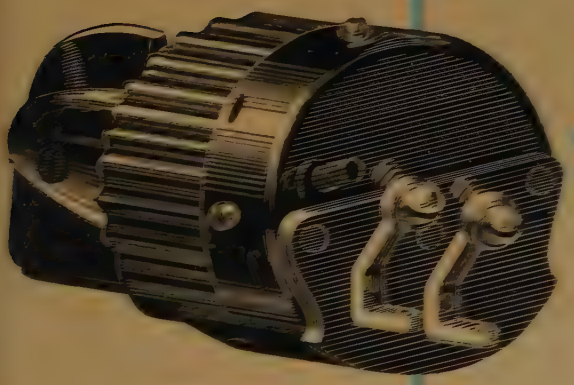

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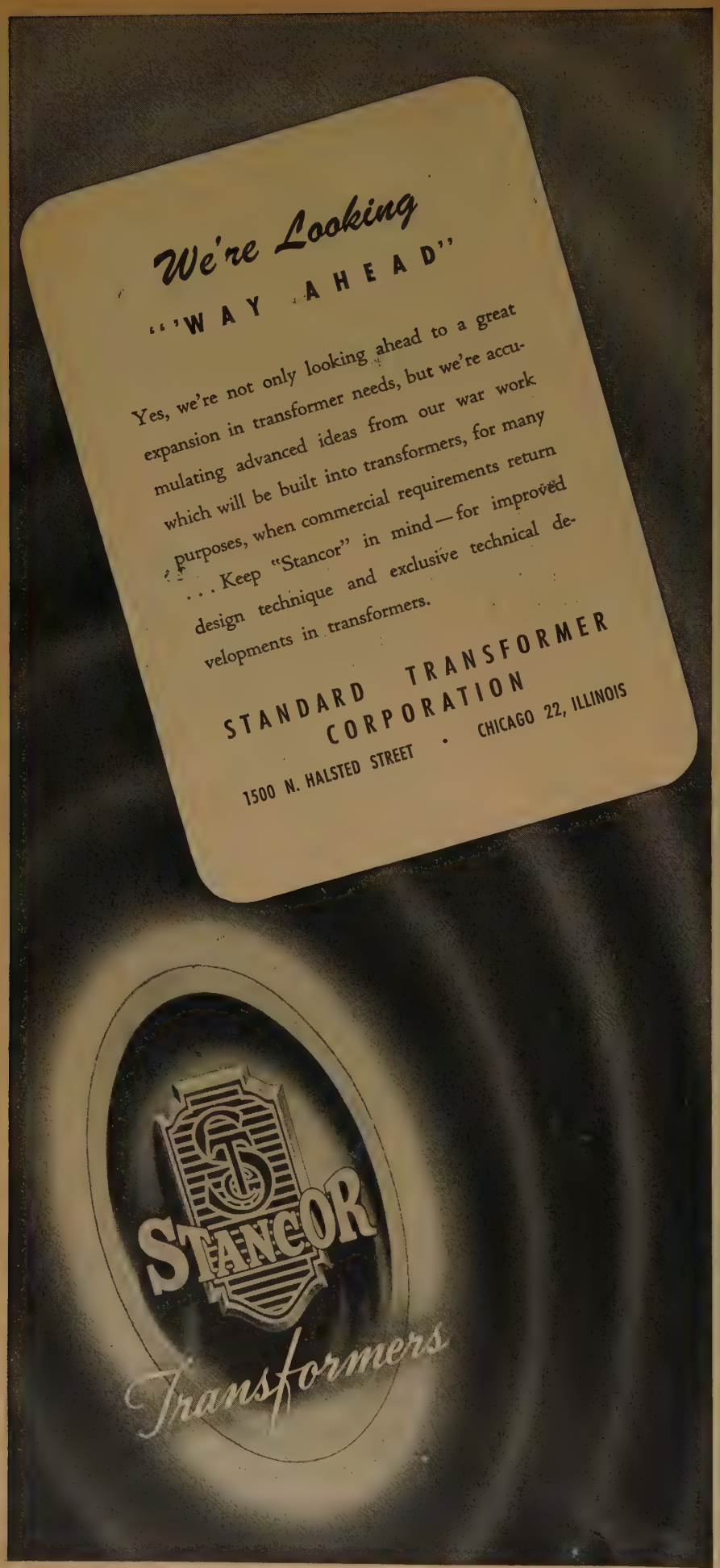
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# Proceedings of the I·R·E

*Published Monthly by*

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VOLUME 32 — *December, 1944* — NUMBER 12

| | | |
|---|---|---|
| Section Meetings | Next Page | |
| Electronic Papers | The Editor | 721 |
| Harry C. Ingles | | 722 |
| Radio-and-Electronic Engineers in War and Peace | Harry C. Ingles | 723 |
| Frederick B. Llewellyn | | 724 |
| Philosophy of Design | C. M. Ashley | 725 |
| Correction to "Noise Figures of Radio Receivers," by H. T. Friis | | 729 |
| A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver | G. L. Beers | 730 |
| Electronic Apparatus for Recording and Measuring Electrical Potentials in Nerve and Muscle | William M. Rogers and Horace O. Parrack | 738 |
| Electrical Glass | Edwin M. Guyer | 743 |
| The Design of an Intermediate-Frequency System for Frequency-Modulated Receivers | William H. Parker, Jr. | 751 |
| Triode Linear Saw-Tooth-Current Oscillator | Leonard R. Malling | 753 |
| Impulse Excitation of a Cascade of Series Tuned Circuits | Samuel Sabaroff | 758 |
| A Calculator for Two-Element Directive Arrays | J. G. Rountree | 760 |
| Institute of Radio Engineers to Act to Secure a Permanent Home | | 768 |
| Institute News and Radio Notes | | 770 |
| Board of Directors | | 770 |
| Executive Committee | | 770 |
| Constitutional-Amendment Section | | 771 |
| 1945 Winter Technical Meeting | | 771 |
| National Electronics Conference | | 771 |
| Correspondence: "Sources of Mica" | H. W. Eckweiler and E. L. Hall | 772 |
| Contributors | | 773 |
| Section Meetings | | 34A |
| Membership | | 36A |
| Positions Open | | 50A |
| Advertising Index | | 72A |

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## NEW YORK, N.Y.—JANUARY 24, 25, 26, AND 27, 1945

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| December 15 | December 15 | December 28 | December 15 | December 19 |
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| January 3 | January 4 | January 8 | January 8 | January 8 |

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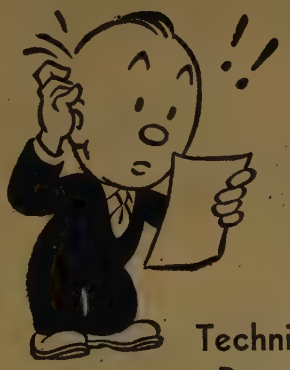

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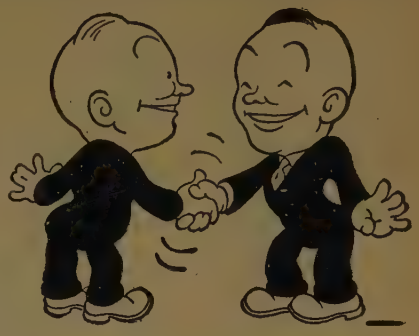


### Annual Meeting:

This is the war-time equivalent of the I.R.E. National Convention and the major annual meeting of the Institute.

### Technical Papers

An exceptionally interesting group of technical papers have been arranged. The trend of the War and approaching peace make valuable the papers planned for this timely meeting.

### President's Luncheon

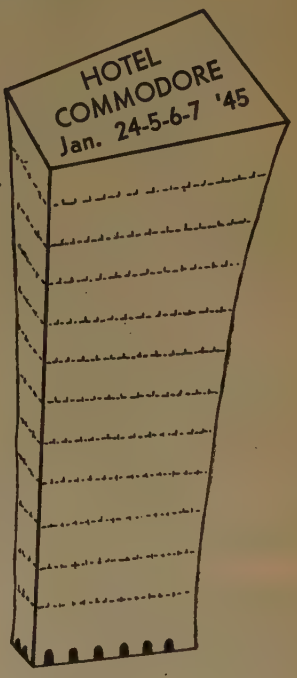
This is just one of many opportunities for friendly greetings our Meeting provides.

### Women's Program

For the first time since 1942, enjoyable activities for women have been arranged and it is hoped many will attend.

### Exhibits

The Radio Engineers' Show has been resumed as a part of the I.R.E. Annual Meeting. 31 Manufacturers will show equipment and component parts on a scale in keeping with War-time conditions.




### Service Men's Program

The Saturday Morning Session will be devoted to papers of special interest to engineers in the Armed Forces.

He reserved his room

### Banquet

The Annual I.R.E. Banquet will be held Thursday Evening, January 25th in the Grand Ballroom. (Informal)

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Only a few short weeks ago, the passions of political partisanship caused human emotions to run high and deep fissures seemed to appear in our national life. Fears and suspicions were aroused, hatred, bigotry, racial prejudice and other subversive doctrines were spread broadcast by campaign orators lacking real issues. Our Axis enemies gloated and saw visions of a soft peace in the success of their "divide and conquer" technique.

But America was too robust and intelligent to be undermined by its greatest asset. American democracy has withstood the acid test of an election in the midst of a war. And its people emerge from a partisan struggle, united and determined to work together for a speedy victory and an enduring peace.

Nothing must be permitted to obstruct or frustrate these historic objectives. Disruptive groups seeking to undermine our harmony, confuse our minds, promote class discord and racial hatred, must be weeded out, isolated, quarantined from American life.

This is a time for national greatness. We are winning this war, winning it because we remain united, because we never lost sight of the crusade and the riches in its victory.

To all of us, there is the common problem of making our country stable, prosperous, contented; of making the world secure, peaceful, democratic. If we jointly accept this problem, the eras ahead for our children are literally golden ones.

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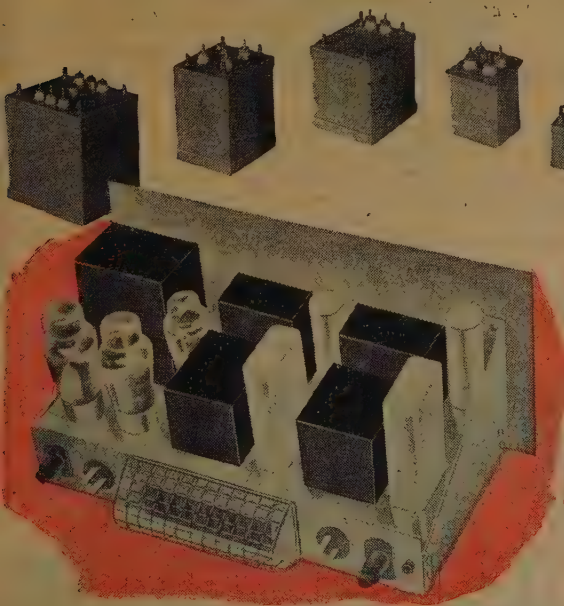


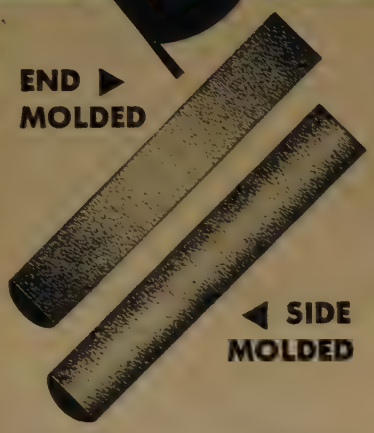
**AMERICAN TRANSFORMER CO., 178 Emmet St., Newark 5, N.J.**

**AMERTRAN**

MANUFACTURING SINCE 1901 AT NEWARK N

**Pioneer Manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission**

# SIDE-MOLDED IRON CORES

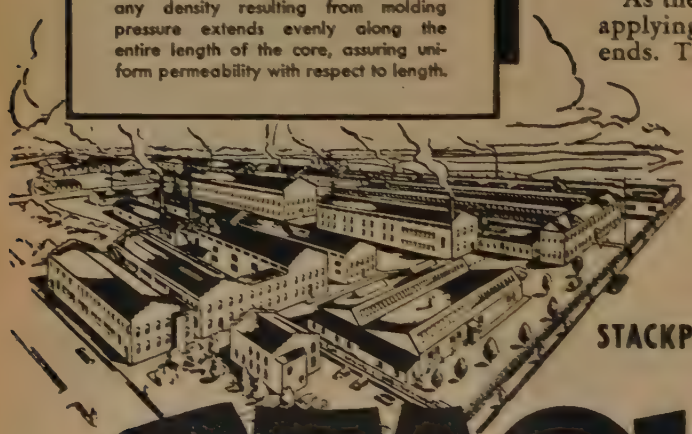



This diagrammatic illustration shows how conventional cores, molded by applying pressure to the ends, results in a dense grouping of iron particles at these points. In side-molded cores, however, any density resulting from molding pressure extends evenly along the entire length of the core, assuring uniform permeability with respect to length.

## Uniform Permeability with Respect to Linearity

Use in many applications has shown Stackpole side-molded iron cores outstandingly superior to conventional end-molded cores for permeability tuning in the broadcast bands. Similar side-molded units are now available for short wave frequencies including television and frequency modulation.

As the name implies, cores of this type are molded by applying pressure from the sides rather than from the ends. The resulting units show very little variation in density or permeability with respect to length, thus assuring a high degree of uniformity.



**WRITE FOR CATALOG!** *Other Stackpole Iron Core types include both standard and high-frequency types; insulated types; iron cores for choke coils, etc. Our new Catalog RC6 describes these as well as fixed and variable resistors, and our complete line of inexpensive line, slide, and rotary-action switches.*

**STACKPOLE CARBON COMPANY, ST. MARYS, PA.**

# STACKPOLE

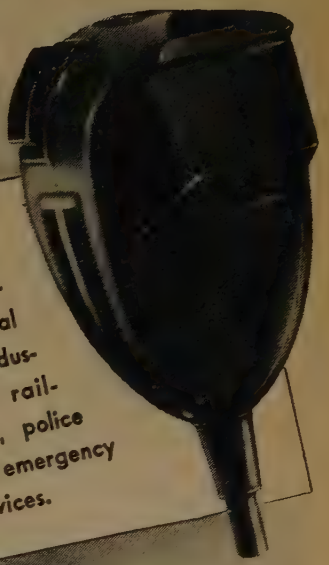
## IRON CORE HEADQUARTERS

# NOW AVAILABLE

**NEW CATALOG, DESCRIBING THE COMPLETE LINE OF**

# Electro-Voice COMMUNICATIONS MICROPHONES

Electro-Voice Differential Microphone, Lip-Type Model 245 for applications where background noise elimination, free use of hands and high articulation are required.



Electro-Voice Differential Carbon Microphone, Hand-Held Model 205-S, an ideal microphone for aircraft, industrial, railroad, police and emergency services.

Electro-Voice Carbon Microphone, Model 210-S, a single button microphone which embodies all of the latest developments required for military use

Electro-Voice Dynamic Microphone, Hand-Held Model 600-D, designed for high fidelity speech pick-up in those locations where the ambient noise does not exceed 100 db.

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# Proving ground for Norelco Cathode Ray Tubes

THE uniform characteristics, long life and outstanding performance of NORELCO Cathode Ray Tubes are the result of exceptional manufacturing skill supplemented by rigid tests applied to each tube as it comes off the production line.

As an example of the care exercised, the electronic test set, shown here, subjects every cathode ray tube to 30 different checks, such as line width, light output, plate alignment, base-to-shell alignment, uniformity of cathode surface, astigmatism, presence of gas, and screen condition. A total of 90 exacting tests of raw materials, parts, sub-assemblies, assemblies and performance guard cathode ray tube quality.

This is typical of the great lengths to which North American Philips goes in producing high performance NORELCO electronic tubes. Behind this company is an organization with world-wide experience resulting from over fifty years of electrical research and development.

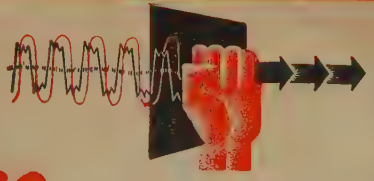
Although all the tubes we produce now go to the armed forces, we invite inquiries from prospective users. A list of tube types we are especially equipped to produce will be sent on request.

Uniformly bright spot on screen of 5 CP1 cathode ray tube in test set indicates perfectly formed cathode.

Pattern used for measuring light output by means of photoelectric cell. Frequency—60 x 2940 cycles.

Trace showing absence of astigmatism. Frequency—60 x 420 cycles.

Write today for interesting booklet, describing the background of North American Philips in the science of electronics.



Norelco Reg. U. S. Pat. Off. *Electronic Products by*

**NORTH AMERICAN PHILIPS COMPANY, INC.**

NORELCO PRODUCTS: Quartz Oscillator Plates; Amplifier, Transmitting, Rectifier and Cathode Ray Tubes; Searchray (X-ray) Apparatus; X-ray Diffraction Apparatus; Medical X-ray Equipment, Tubes and Accessories; Electronic Measuring Instruments; High Frequency Heating Equipment; Communications Equipment; Tungsten and Molybdenum products; Fine Wire; Diamond Dies. When in New York, be sure to visit our Industrial Electronics Showroom.

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Factories in Dobbs Ferry, N. Y.; Mount Vernon, N. Y. (Metalix Div.); Lewiston, Me. (Elmet Div.)

**COLONEL JOHN CASEY, *Manager, Chicago Municipal Airport . . .***

*Colonel Casey said, "The growing complexities of airport traffic make it ever more important that private planes and regular operating passenger aircraft be equipped with up-to-date, reliable two-way radio, if high standards of safety are to be maintained. One important factor is . . ."*

# "A FOOLPROOF POWER SUPPLY FOR AIRCRAFT RADIO OPERATION"

Colonel Casey, Electronic Laboratories has long been aware of the need for reliable power supplies especially adapted for aircraft use. One of E-L's exclusive developments along this line involves vibrators operating in parallel which assures a reserve power source for extra protection. These Vibrator Power Supplies—both light and heavy duty—are specially designed for complete reliability at very high altitudes.

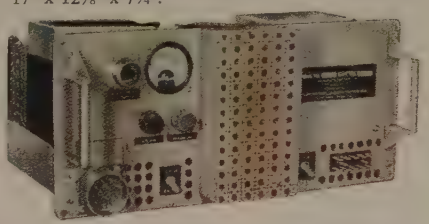
The life of E-L Vibrator Power Supplies is far beyond the customary overhaul requirement. With these units maintenance time is cut to a minimum—only a small fraction of the time previously required.

Other E-L developments for the aircraft field include units for flashing wing lights and for instrument panel illumination. This equipment has wide application for the light plane field as well as for large aircraft.

The economy and versatility of Vibrator Power Supplies are also available to the marine field—where units have been designed to provide fluorescent lighting, radio-telephone operation and electrical appliance use—as well as many other fields where it is necessary to convert current to specific voltage and type requirements . . . Let E-L engineers consult with you on your power supply problem.

**STANDARD POWER SUPPLY**
**MODEL SC-1096**

Model SC-1096 is a typical E-L Vibrator Power Supply which meets the requirements of aircraft radio use. This unit was designed for the Canadian Signal Corps to operate radio transmitters. Input voltage: 12 volts DC, or 110-117 volts AC at 50-60 cycles. Output voltage: 2000 volts at 125 ma., 400 volts at 25 ma., 250 volts at 10 ma., 250 volts at 5 ma., 10 volts at 5 amps., 12 volts at 1 amp. Output power: 480 watts. Dimensions: 17" x 12⅜" x 7¾".



**Electronic LABORATORIES INC.**
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VIBRATOR POWER SUPPLIES FOR LIGHTING, COMMUNICATIONS, AND ELECTRIC MOTOR OPERATION • ELECTRIC, ELECTRONIC AND OTHER EQUIPMENT

# AGAIN!

ARMY E NAVY

*For the 5th time Hallicrafters employees win Army-Navy "E" Award!*

First exclusive manufacturer of short wave radio equipment to receive the coveted Army-Navy "E" Award for the fifth time... the result of the continued and untiring devotion to duty of the company's 1,500 employees.

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# THE BEST KNOWN NAMES ON THE WAR PRODUCTION FRONT DEPEND ON THORDARSON QUALITY

Throughout the trying periods encompassed by 3 wars . . . and in all the intervening years of peace since 1895 . . . Thordarson leadership has been accentuated by its association with the most outstanding concerns in America.

Especially on the present world-wide war fronts...where the marvels of research laboratories and the handiwork of production geniuses may be seen in action...there also will be found the results of Thordarson experience and Thordarson engineering ability.

Thordarson Transformers and Amplifiers are "good right hands" to a host of America's leading organizations who are concentrating on winning the war as quickly as possible. Thordarson products are helping to do everything from making communications easier and more accurate to conducting fatigue tests which insure more dependable airplane propellors. All of these services and experiences, now devoted to war, will enable us to serve you better when peacetime needs are again paramount.

ARMY E NAVY

THORDARSON

TRANSFORMER DIVISION
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500 WEST HURON STREET, CHICAGO, ILL.

Transformer Specialists Since 1895
. . ORIGINATORS OF TRU-FIDELITY AMPLIFIERS

# welding with a paint brush?

*Alloy flows easily and weld is quickly completed under arc.*

To solve a difficult welding problem, Eimac laboratory technicians compounded a welding alloy that could be applied with a paint brush. The alloy flows easily under an arc to complete the weld, yet subsequent heating to temperatures as high as 2900 degrees Centigrade will not destroy the weld.

Such is but an example of the application of the Science of metallurgy in the "science behind the science of electronics." The extent to which Eimac Engineers went to solve this relatively small problem reveals two important facts:—(1.) The thoroughness of Eimac Engineering, and (2.) The completeness of their engineering facilities. The leadership which Eimac tubes enjoy throughout the world in all phases of electronics is attributable to the soundness of this engineering.

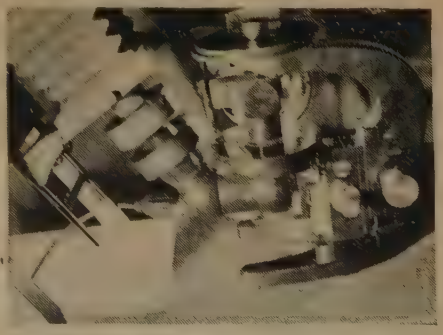
Performance of any electronic equipment is a direct reflection of the performance of its vacuum tubes. Hence it is advisable for users and prospective users of electronics to look first to the vacuum tube requirements. Because Eimac makes electron vacuum tubes exclusively their advice to you is unbiased and can be of great value. A note outlining your problem will bring such assistance without cost or obligation.

## *The Science Behind the Science of Electronics*

*is the focusing of all branches of science upon the development and improvement of electron vacuum tubes.*

*SPECTROGRAPH... Analysis determines exact characteristics of metals to be joined.*

*METALLURGY... Compounding special alloy of metals.*



*OPTICS... For studying the effects of processing.*

*ELECTRONICS... Welded elements in electron vacuum tubes withstand tremendous heat.*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*Write for your copy of Electron Tubes—a 64 page book in fully illustrated—covering fundamentals of Electronics and many of its important applications. Written in layman's language.*

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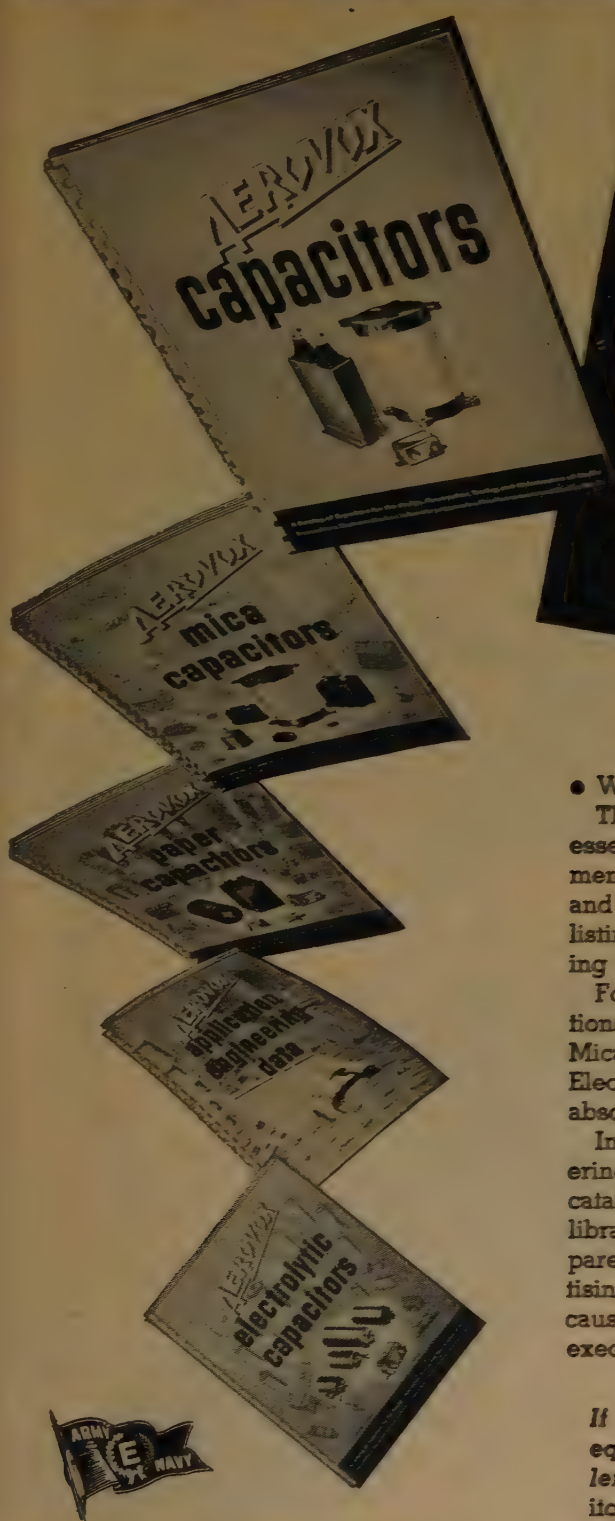


# NEW 152-PAGE CAPACITOR CATALOG

**Contains Application Engineering Data and Separate Sections on MICA, PAPER, and ELECTROLYTIC CAPACITORS**

● Why essential? That's a big statement. Let us qualify:

This new Aerovox Catalog contains that information which is essential to those who design and build radio-electronic equipment. Here is general and specific engineering data on capacitors and their applications; detailed specifications on various types; listings of recommended types and ratings; special notes covering special features and special types; color codes; etc.

For greater convenience, the catalog is divided into four sections, each with its tab-indexed cover. These sections comprise Mica Capacitors, Application Engineering Data, Paper Capacitors, Electrolytic Capacitors. The plastic binding permits pages to lie absolutely flat.

In preparation for a year and a half—involving widespread gathering of data and intensive compilation—this combination manual-catalog represents an outstanding contribution to the working library of the radio-electronic engineer and executive. It was prepared BY engineers FOR engineers; contains absolutely no advertising—just information on capacitance and capacitors. And because of cost, its circulation is strictly limited to engineers and executives.

**● Write for Your Copy...**

*If you are engaged in designing or building radio-electronic equipment of recognized standing, write on your business letterhead* for your registered copy. Also submit your capacitor problems and requirements for our collaboration.

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As the field of Electronics broadens and new, more complex equipment goes into service the need for more accurate test and measuring instruments becomes greater. The war has lent great impetus to the progress of Electronics and has accordingly accellerated the development of Electronic instruments. Into the past two years have been crowded a normal ten years of technological progress.

Today the most advance developments are not being released for general use. However, today is not too soon for you to make your plans for post-war activity. And, along that line, you should make note of the fact that *-hp-* engineering is in the vanguard of electronic instrument developments.

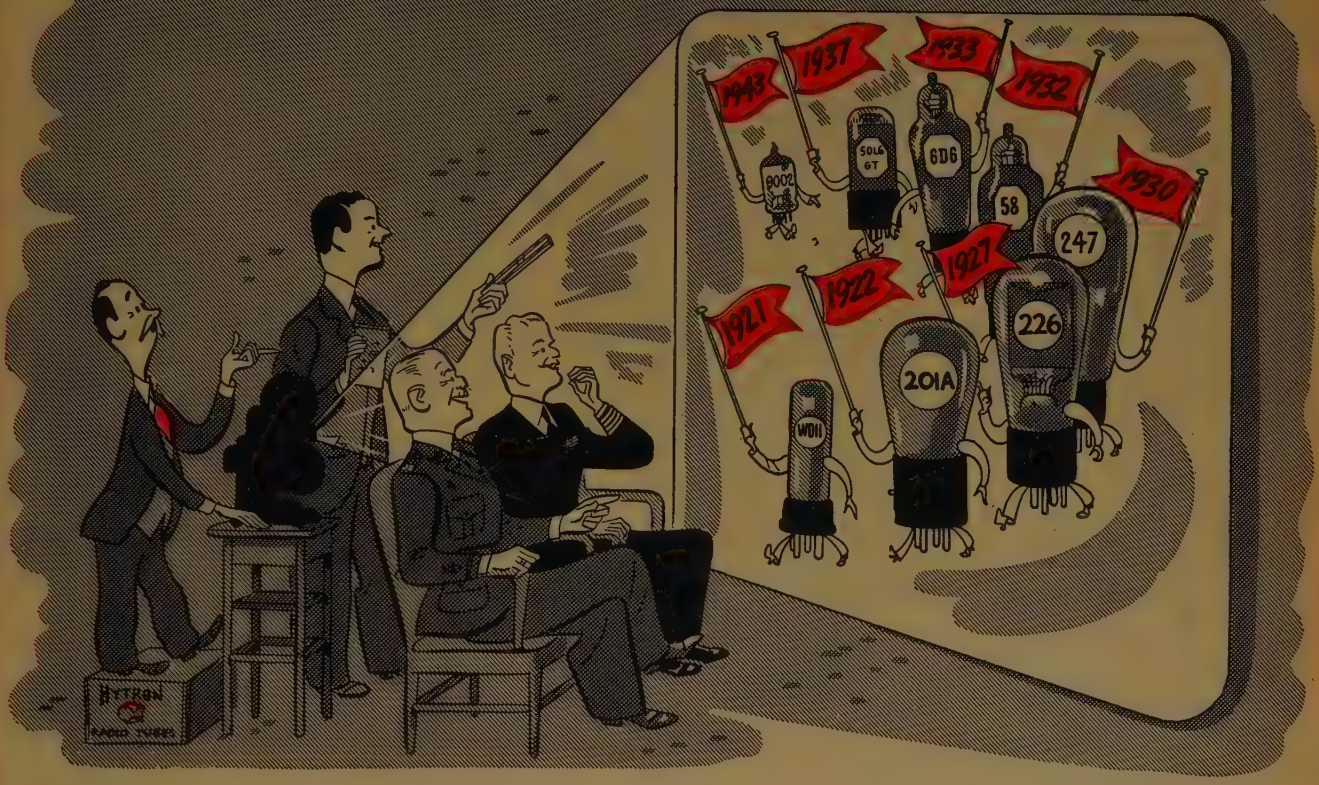
Oscillators to test wide range television channels, new high frequency signal generators, special signal generators for F. M. use, new vacuum tube voltmeters . . . all providing split-hair accuracy for more exacting measurements and ruggedly constructed to perform in the field under circumstances of war, are examples which merely hint of the better things to come.

*-hp-* engineering is at your service, whether your problem is immediate or for post-war. Write today, there is no cost or obligation. Direct Canadian inquiries to Atlas Radio Corporation, 560 King Street West, Toronto 2, Canada.

**HEWLETT-PACKARD COMPANY**

**Box 927D Station A, Palo Alto, California**

# HYTRON has made them all!




The march of Hytron receiving tube progress down through the years is fascinating. One looks back on tubes, tubes, and more tubes: battery, AC, AC/DC, diodes, triodes, pentodes, beam tetrodes, multiple purpose types, G's, MG's, BANTAM GT's — and now the miniatures. Price and size have been drastically cut; quality and performance, amazingly improved.

Hytron has made them all. Its long and varied experience is priceless in a complex industry where probably never will all the answers be known. In making radio tubes, painfully acquired practical experience must supplement the formulae of science.

With an eye to present and future, Hytron is concentrating its production of receiving tubes on preferred BANTAM GT types needed for war — for today's civilian replacements — and ultimately for post-war. Its wartime activities are teaching Hytron new techniques of miniature production. Many potentially popular Hytron miniatures are in development. Typical American dissatisfaction with anything but perfection continues; the parade of Hytron receiving tubes marches on.

OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

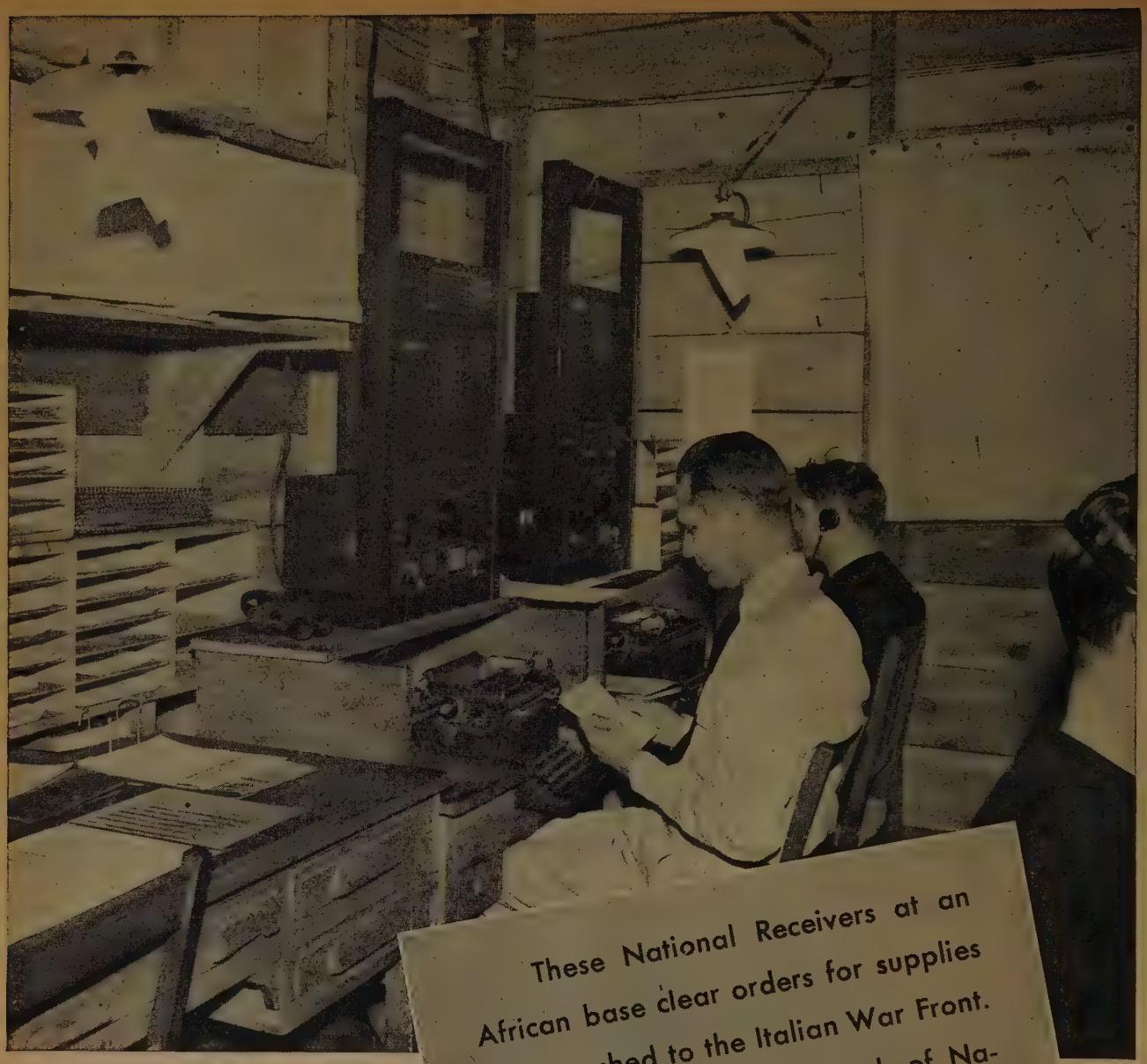
**HYTRON CORPORATION** ELECTRONIC AND RADIO TUBES

SALEM AND NEWBURYPORT, MASS.

ARMY NAVY

HYTRON RADIO TUBES

BUY ANOTHER WAR BOND



These National Receivers at an African base clear orders for supplies being rushed to the Italian War Front. They are typical of thousands of National Receivers in key spots throughout the world, serving the Armed Forces with superb dependability and performance.

# NATIONAL COMPANY

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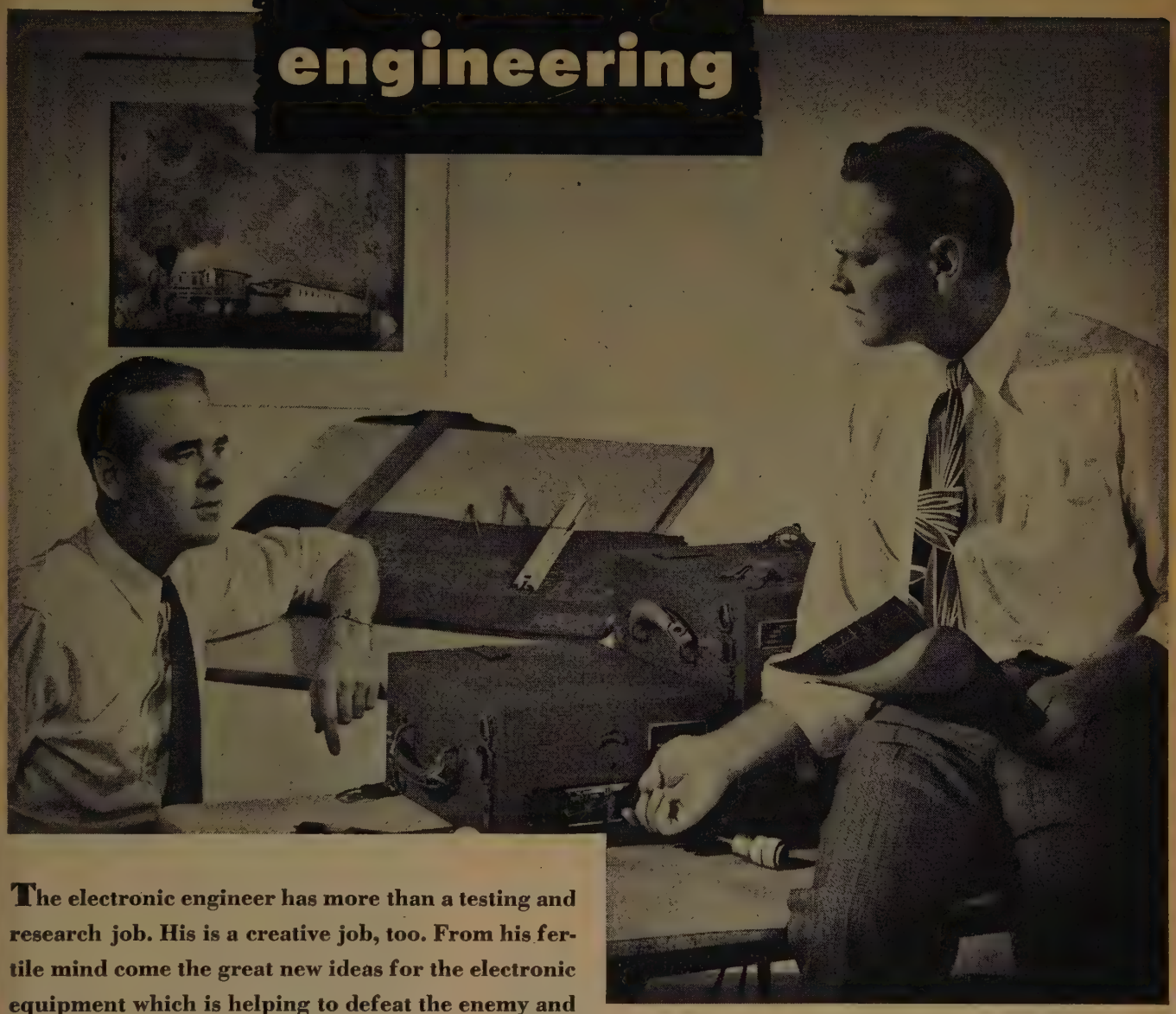
NATIONAL RECEIVERS ARE IN SERVICE THROUGHOUT THE WORLD

# creative engineering



**The electronic engineer has more than a testing and research job. His is a creative job, too. From his fertile mind come the great new ideas for the electronic equipment which is helping to defeat the enemy and which will mean a glorious peacetime era when peace is assured. Most all industries will benefit from the highly specialized technical and scientific knowledge of the electronic engineer and the discoveries he has made.**

**Raytheon is proud of its part in the immeasurably important role that advanced electronic equipment is playing in winning the war. When peace comes, Raytheon's research and wartime production knowledge will be used to doubly protect the electronic equipment requirements of post-war radio and industrial products manufacturers, and to assure Raytheon's continued leadership in the electronic era.**

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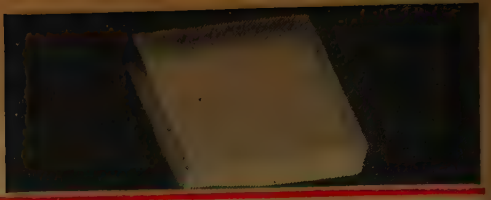
Awarded All Four Divisions of Raytheon
for Continued Excellence in Production

RAYTHEON
Raytheon Manufacturing Company
ELECTRICAL EQUIPMENT DIVISION
Waltham and Newton, Massachusetts

DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES AND EQUIPMENT FOR THE NEW ERA OF ELECTRONICS



# AAC CRYSTALS

The recognized quality and dependability of AAC quartz crystals is the result of AAC's wide experience as one of America's largest producers of transmitters and other precision radio equipment. AAC quartz crystals and crystal units have proved so outstanding in meeting intricate specifications and exacting requirements that they are today demanded by many of the world's greatest airlines, radio manufacturers, various branches of the armed services and other government agencies.

This practical achievement background—*plus* AAC's staff of skilled engineers and modern-to-the-minute manufacturing facilities is ready to meet your crystal needs advantageously. Rapid delivery of standard types—also special types, ground and mounted to your specifications.

**ELECTRONICS DIVISION**
**Kansas City, Kansas**

WRITE now for your free copy of the new AAC crystal catalog giving detailed facts about AAC quartz crystals and crystal units.

AAC Products

**AIRCRAFT RADIO and**
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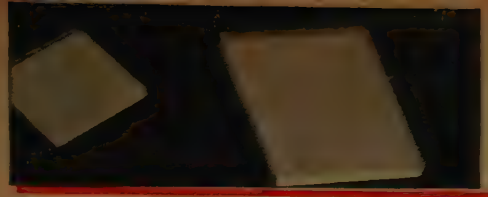

# PRECISION MADE FOR PRECISE PERFORMANCE *and*

# PROVED IN USE!

There is no question about AAC crystals meeting the most exacting requirements under severe operating conditions. Their reliability has been tested and proved a thousand times over . . . in battlefront service to the armed forces . . . in helping to keep the communication systems of many leading airlines working efficiently . . . in meeting the quality demands of radio manufacturers. The list of users of AAC crystals shown below is a tribute to the engineering skill and fine manufacturing facilities behind AAC crystals.

**Braniff Airways, Inc.**
**Chicago & Southern Air Lines, Inc.**
**National Airlines, Inc.**
**Northwest Airlines, Inc.**
**Pan American Airways System**
**Pan American-Grace Airways, Inc.**
**Pennsylvania-Central Airlines Corp.**
**Transcontinental & Western Air, Inc.**

**Colonial Radio Corp.**
**Columbia Broadcasting System, Inc.**
**Stewart-Warner Corporation**
**Western Electric Company, Inc.**
**Zenith Radio Corporation**

*Remember,* crystal production is only one of AAC's services to the aviation and electronics industries. The production of airborne and ground radio equipment at the rate of more than 30 million dollars yearly for U. S. government and leading airlines demonstrates the wide scope and high rating of AAC manufacturing ability.

B-184

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**ELECTRONICS • ENGINEERED POWER CONTROLS**

New York, N. Y. Burbank, Calif. Cable Address: AACPRO

# It's the Smallest 2-Watt Fixed Resistor

## BRADLEYOMETER

### The World's Finest Continuously Adjustable Resistor

The only continuously adjustable composition type resistor (only 1 inch diameter) having a rating of 2 watts with substantial safety factor. Has solid molded resistor unit . . not a film, spray, or paint type. Any resistance-rotation curve available.

Type JS Bradleyometer with built-in line switch. Not affected by heat, cold, or moisture.

Type J Bradleyometers may be used singly or assembled into multiple controls.

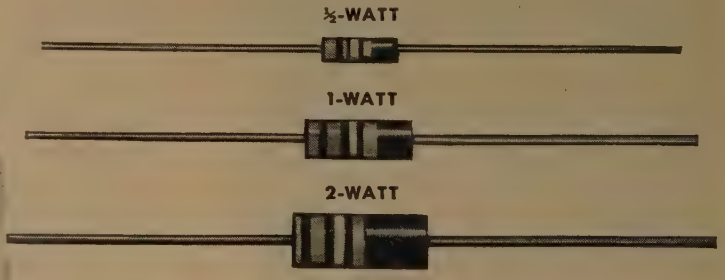
Low resistance carbon brush makes contact with surface of molded resistor.

ONLY $\frac{11}{16}$-inch long . . and $\frac{1}{4}$-inch diameter . . those are the remarkably small dimensions of the NEW Type HB Bradleyunit. It is the smallest 2-watt insulated fixed resistor ever produced, but you can use it safely right up to its listed rating. You don't have to derate it for even the toughest application.

The Type HB 2-watt Bradleyunit will pass all American War Standard tests: It is outstanding in its humidity and temperature characteristics. It matches in dependability and fine appearance the Allen-Bradley ½-watt and 1-watt Bradleyunits (see below) which are recognized as "tops" by all radio and radar men.

Available in R. M. A. standard values from 10 ohms to 0.47 megohms in tolerances of 5, 10, and 20 per cent. Specify the Type HB 2-watt Bradleyunit and be safe in your engineering.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis.




# ALLEN-BRADLEY

## FIXED & ADJUSTABLE RADIO RESISTORS

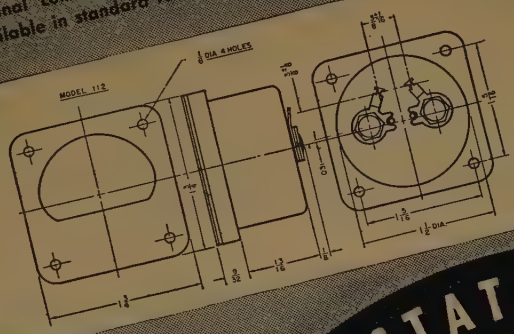
QUALITY

# For special requirements

## DeJUR ELECTRICAL INSTRUMENTS

### 1½ INCH METER · SQUARE TYPE · MODEL 112

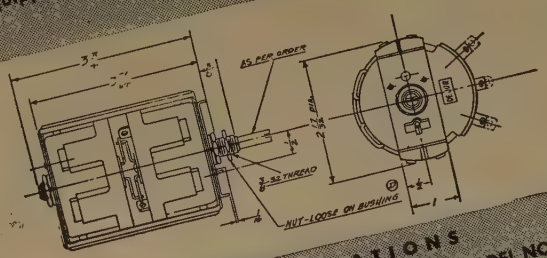
This miniature instrument may be successfully used in a variety of applications, and it is particularly useful where space is an important factor. The DeJur 112 measures only 1¾" square and 25/32" deep, and uses basically the same carefully designed components as our larger instruments. In order to conserve space, soldering lugs are used for the terminal connections instead of the conventional studs. Available in standard ranges.




## DeJUR RHEOSTAT-POTENTIOMETERS

### MODEL 241 D

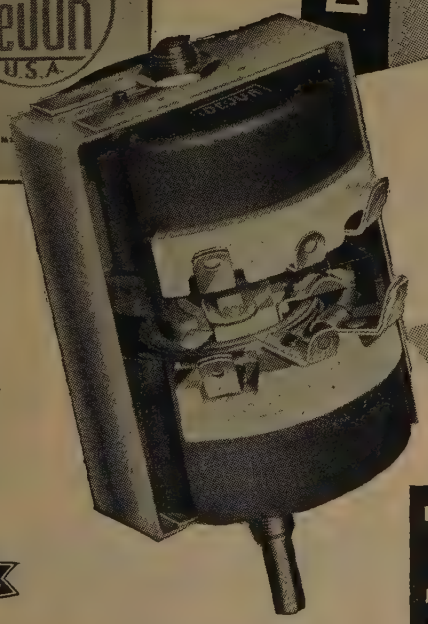
A dual unit model, with both units mounted together. The Model 241 D is typical of the many types developed by DeJur engineers for special requirements. We are equipped to serve your needs, too.




**SPECIFICATIONS**

50 WATTS
RANGES—10 to 10,000 Ohms
MECH. ROTATION—300°
ELEC. ROTATION—270°
WEIGHT—7 Oz.

| RANGE IN OHMS | MODEL NO. |
|---|---|
| 0. 10 | 241 D |
| 0. 50 | 241 D |
| 0. 100 | 241 D |
| 0. 500 | 241 D |
| 0. 1,000 | 241 D |
| 0. 5,000 | 241 D |
| 0. 10,000 | 241 D |



**Write for the NEW DeJur Catalog**

ARMY E NAVY

*Buy and Hold More WAR BONDS*

## DeJur-Amsco Corporation

GENERAL OFFICE: NORTHERN BLVD. AT 45th ST., LONG ISLAND CITY 1, N. Y.

# *Something to Remember*
## *about having your* CAPACITOR SPECIFICATIONS MATCHED

**SPRAGUE CAPACITOR TYPES**

Dry Electrolytic
Paper Dielectric
Mica Dielectric
Power Factor Correction
Motor Starting
High Voltage Networks
Radio Noise Suppression Filters, etc., etc.

In designing or producing a radio or electrical product, there are plenty of things to think of besides capacitors. Moreover, unless you've specialized, it's difficult to keep fully abreast of modern capacitor developments. That's why we make this suggestion:

Write today for a supply of Sprague Sample Request Forms. Then, as capacitor applications arise, use these forms to send full details to Sprague engineers. Let them make suggestions. Benefit from their broad experience, as well as from the fact that Sprague regularly produces dozens of standard Capacitor types, plus hundreds of adaptations and special units.

Such a request places you under no obligation to buy the recommended type. It simply assures you of specialized attention in the selection of an important component on which there are many factors to consider—angles which cannot always be cataloged completely or promptly, or which cannot be uncovered in any other way than through this personalized engineering service.

Write today for a supply of Capacitor Sample Request Forms.

**SPRAGUE ELECTRIC COMPANY, North Adams, Mass.**
*(Formerly Sprague Specialties Co.)*

A typical group of Sprague Dry Electrolytic Capacitors designed to match special specifications.

# SPRAGUE

## CAPACITORS • KOOLOHM RESISTORS

T. M. REG. U. S. PAT. OFF.

*Casting the International Meter Rods in Paris 1874. The degree of accuracy attained 1/10,000,000 of a quadrant of a terrestrial meridian.*

# WHO SETS THE *Quality Standard* FOR TRANSMITTING TUBES

# UNITED

## TRANSMITTING TUBES

IN every art or craft, the work of some acknowledged master sets the standard.

Since 1934 UNITED has won recognition by specializing exclusively in the engineering, design and building of transmitting tubes which are unchallenged for excellence. UNITED tubes excel in every electronic application . . . including radio communication, physiotherapy, industrial control and electronic heating. In these and other applications, tubes by UNITED continue to win top honors for uniformly dependable performance.

In communication equipment for airlines, commercial broadcasting, police radio stations and other vital civilian services, UNITED transmitting tubes set the standard. Accept nothing less than UNITED quality tubes for your requirements.

*Order direct or from your electronic parts jobber.*

**UNITED ELECTRONICS COMPANY**

NEWARK, 2 New Jersey

*Transmitting Tubes EXCLUSIVELY Since 1934*

# KEN-RAD *Metal Tubes*

The weight and space saving advantages of Ken-Rad "self-shielding" metal tubes have long been recognized Their sturdy ruggedness under severe service conditions in fighters and bombers is a matter of record

• Write for your copy of "Essential Characteristics" the most complete digest of tube information available

TRANSMITTING TUBES
CATHODE RAY TUBES
SPECIAL PURPOSE TUBES
RECEIVING TUBES
INCANDESCENT LAMPS
FLUORESCENT LAMPS

**KEN-RAD**

EXECUTIVE OFFICES
OWENSBORO · KENTUCKY
EXPORTS 13 MOORE STREET NEW YORK

# Another big rush on Long Distance lines this Christmas . . .

It was a big rush last year. It may be even bigger this Christmas.

So please help keep Long Distance lines clear for essential calls on December 24, 25 and 26.

War still needs the wires — even on holidays.

BELL TELEPHONE SYSTEM

# *An Important Statement*

# BY MYCALEX CORPORATION OF AMERICA

## Issued in an Effort to Clear up and to Avoid Continued Confusion in the Trade.

**It has come to our attention that in some quarters electronic engineers and purchasing executives are under the erroneous impression that the MYCALEX CORPORATION OF AMERICA is connected or affiliated with others manufacturing glass-bonded mica insulation, and that genuine "MYCALEX" and products bearing similar names are all "the same thing" . . . are "put out by the same people" . . . and "come from the same plant."**

## These are the FACTS:

1. The MYCALEX CORPORATION OF AMERICA is not connected or affiliated with any other firm or corporation manufacturing glass-bonded mica insulating materials.

2. The word "MYCALEX" is a registered trade-mark owned by MYCALEX CORPORATION OF AMERICA, and identifies glass-bonded mica insulating materials manufactured by MYCALEX CORPORATION OF AMERICA.

3. The General Electric Company, by virtue of a non-exclusive license it had under a MYCALEX patent through the MYCALEX (PARENT) COMPANY LTD., has been permitted use of the trade-mark "MYCALEX" on its glass-bonded mica insulating materials.

4. The MYCALEX CORPORATION OF AMERICA has behind it over 20 years of research leadership, dating back to work done by the original MYCALEX (PARENT) COMPANY, LTD. of Great Britain, from which it obtained its American patents. MYCALEX CORPORATION OF AMERICA owns U. S. patents and patent applications on improved glass-bonded mica insulation marketed under the trade-mark "MYCALEX".

5. The products of MYCALEX CORPORATION OF AMERICA are: (a) "MYCALEX 400"—the most highly perfected form of MYCALEX insulation, approved by the Army and Navy as Grade L-4 insulation. MYCALEX 400 is sold in sheets, rods and fabricated form. (b) "MYCALEX K"—an advanced capacitor dielectric with a dielectric constant of 10 to 15, which can be fabricated to specifications. (c) MOLDED MYCALEX available to specifications in irregular shapes and into which metal inserts may be incorporated.

6. "MYCALEX" in the forms described above is made by exclusive formulae and exclusive patented processes. It is utterly impossible for any one other than the MYCALEX CORPORATION OF AMERICA to offer any product, similar in appearance, as "the very same thing."

MYCALEX CORPORATION *of* AMERICA

*"Owners of 'MYCALEX' Patents"*

Plant and General Offices
CLIFTON, N.J.

Executive Offices: 30 ROCKEFELLER PLAZA
NEW YORK 20, N.Y.

# . . . How MYCALEX Solved a Tough Insulating Problem for HAZELTINE ELECTRONICS and the NAVY . . .

HAZELTINE ELECTRONICS CORPORATION

PLANT
58-25 LITTLE NECK PARKWAY
LITTLE NECK, LONG ISLAND
FLUSHING 7-0300

EXECUTIVE OFFICES
1775 BROADWAY
NEW YORK 19, N. Y.

ARMY (E) NAVY

TELEPHONE
COLUMBUS 5-0781
TELETYPE - NY 1-2880

September 15, 1944

Mycalex Corporation of America
30 Rockefeller Plaza
New York, N. Y.

Attention: Mr. Jerome Taishoff, President

Gentlemen:

In the development of special apparatus, to be supplied on a Navy contract by Hazeltine Electronics Corporation, it was found necessary to utilize a material with a dielectric constant of 12-15.

We put our problem in the hands of your company.

The cooperation which we received from your organization is to be very highly commended. The special material, which was developed after much experimentation and research on your part, has maintained a constant dielectric all through production.

We have delivered a quantity of these units to the Navy, and we wish to again thank you for the large part you played in making the delivery of these vital equipments possible.

Very truly yours,

J. E. Gray

J. E. GRAY
Co-ordinating Engr.

Note one more success story concerning MYCALEX and an outstanding builder of electronic apparatus. MYCALEX—the "last word" in low-loss insulation—may be the right answer to *your* problem, too. Write for detailed specifications and samples.

MYCALEX
THE INSULATOR
TRADE MARK REG. U. S. PAT. OFF.

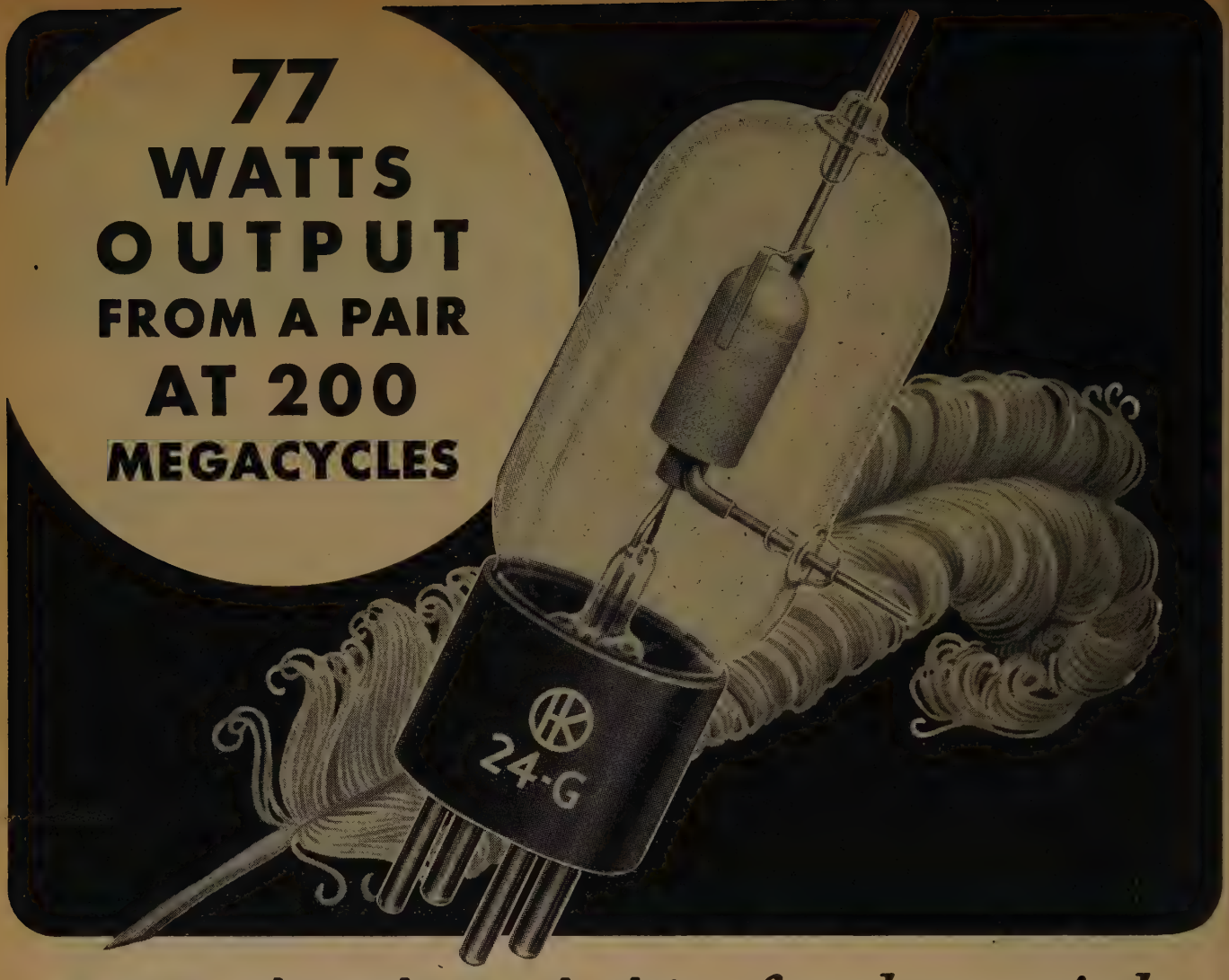
## MYCALEX CORPORATION OF AMERICA

*"OWNERS OF 'MYCALEX' PATENTS"*

CLIFTON, NEW JERSEY

*Executive Offices:* 30 ROCKEFELLER PLAZA NEW YORK 20, N. Y.

# 77 WATTS OUTPUT FROM A PAIR AT 200 MEGACYCLES




# H & K developed this *featherweight* to pack a wallop in the VHF region

The only thing that's small about this 4½-inch, 1½-ounce Gammatron is its size. Heintz and Kaufman engineers originated and perfected this powerful little tube to put out a 77 watt signal from a pair at 200 Mc. as a Class C unmodulated amplifier . . . 116 watts at 100 Mc. Even at peak frequency, 300 Mc., a pair of HK-24G Gammatrons develop a remarkable 44 watts.

The high efficiency of the HK-24G in the VHF region results from (1) the long, capped tantalum plate, typical of Gammatrons, which confines the entire electron stream for useful output, and (2) the fact that this grid is closely spaced to the filament for short electron time-flight.

The HK-24G triode is easy to neutralize, and parasitic oscillation is avoided, because the inter-electrode capacities are very low, and the grid and plate leads are short. For typical operating ratings of the HK-24G as an r. f. power amplifier, audio amplifier, crystal oscillator, doubler, or tripler, write today for data.

**HK-24G MAXIMUM RATINGS**

| | |
|---|---|
| Power Output Class "C" R. F. | 90 Watts |
| Plate Dissipation | 25 Watts |
| Amplification Factor | 25 |
| Plate Voltage | 2000 Volts |
| Plate Current | 75 MA |
| Grid Current | 25 MA |
| Frequency | 300 MC |

**INTER-ELECTRODE CAPACITIES**

| | |
|---|---|
| C Grid-Plate | 1.6 UUF |
| C Grid-Filament | 1.8 UUF |
| C Plate-Filament | 0.2 UUF |

**FILAMENT**

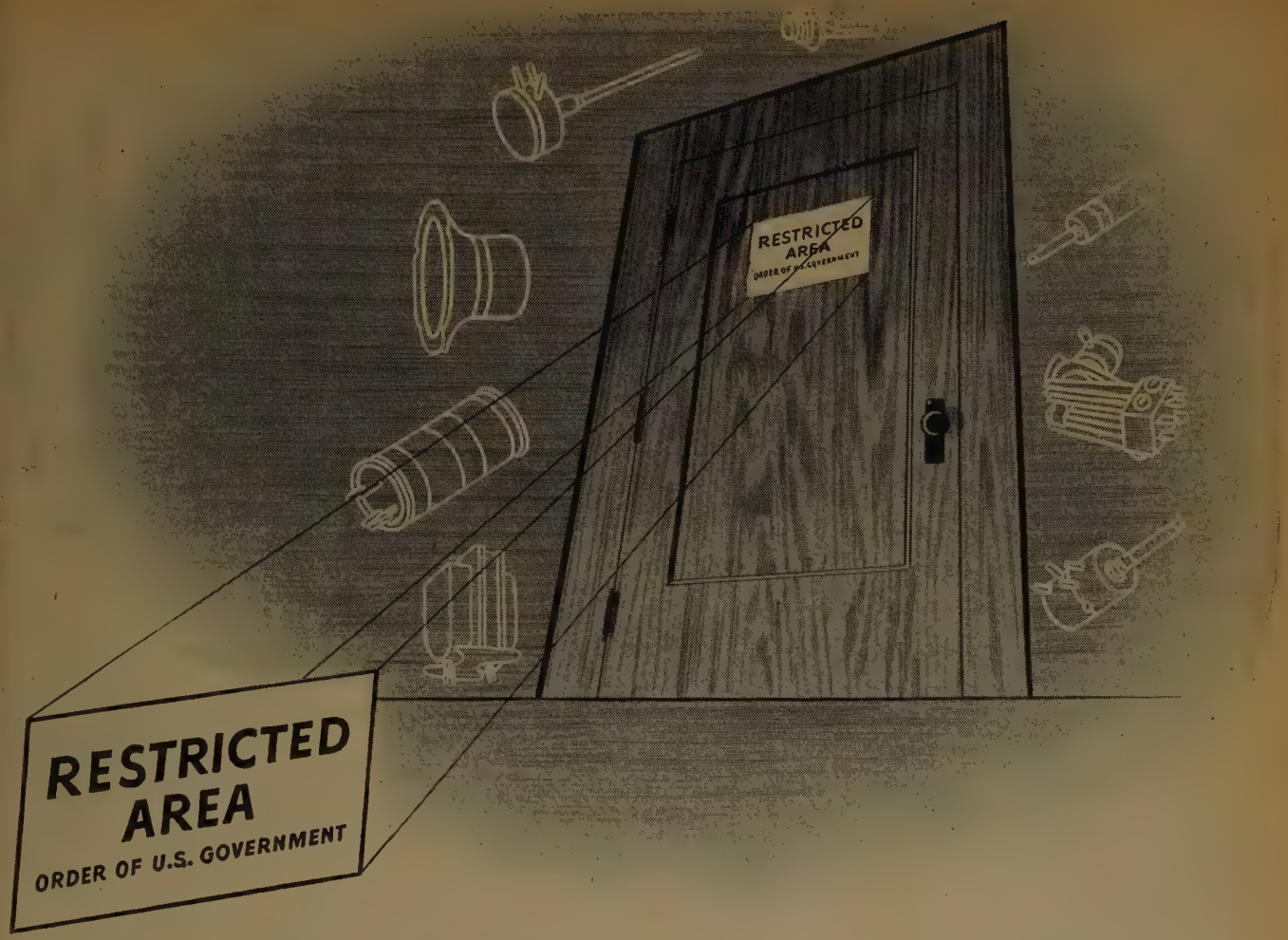
Volts, 6.3 Amperes, 3

**LOAN YOUR DOLLARS**
**DONATE YOUR BLOOD**
**FOR EARLY VICTORY**

## HEINTZ AND KAUFMAN LTD.

SOUTH SAN FRANCISCO • CALIFORNIA

*Gammatron Tubes*

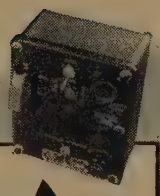



# *locked door . . .*

● Forbidden to all but top government officials and Utah technicians . . . this room has been the birthplace of many miracles in radio, electronics and electricity. Behind this locked door, Utah has developed vital equipment . . . earmarked for military needs. Inevitably, the wartime secrets of this forbidden room will be adapted to commercial and consumer needs . . . assume a prominent role in the pursuits of peace.

★ ★ ★

**Every product made for the trade, by Utah, is thoroughly tested and approved**



***Keyed to "tomorrow's" demands: Utah transformers, speakers, vibrators, vitreous enamel resistors, wirewound controls, plugs, jacks, switches and small electric motors.***

**utah**

ARMY E NAVY

**Utah Radio Products Company, 842 Orleans Street, Chicago 10, Ill.**

Through the development of our own highly specialized calibrating equipment Hammarlund engineers have made possible mass production of variable capacitors with accuracies comparable to laboratory standards.

HAMMARLUND

THE HAMMARLUND MFG. CO., INC., 460 W. 34TH ST., N. Y. C.

MANUFACTURERS OF PRECISION COMMUNICATIONS EQUIPMENT

# In QUARTZ CRYSTALS, the most significant advancements have been introduced by Bliley

This is a message from Bliley to the thousands of amateurs and professional engineers who are now serving their country in the armed forces and in essential communications industries. Bliley "grew up" with them.

To these men and women Bliley crystals are still a familiar sight. They recognize, in the military crystal units used by our armed forces, many basic features that were pioneered by Bliley for application in peacetime services.

When tremendous production was demanded by our armed forces Bliley had the engineering background, the facilities and the production experience to provide a firm corner stone on which this volume production of radio crystals was successfully built. And, from the ranks of talented amateurs and radio engineers came a host of long-time friends who knew exactly how to use them.

But research has continued and experience has grown mightily to meet the challenge of war requirements. With the return to peace, and relaxation of wartime restrictions there will be better Bliley crystals for every application as well as new Bliley crystals for the new services that loom on the horizon. That's a promise.

To our old friends, amateurs and professional engineers, we say, "Look to Bliley for crystal units that embody every advanced development."

**Bliley CRYSTALS**

**Do more than before . . .**

**buy extra War Bonds**

**BLILEY ELECTRIC COMPANY**

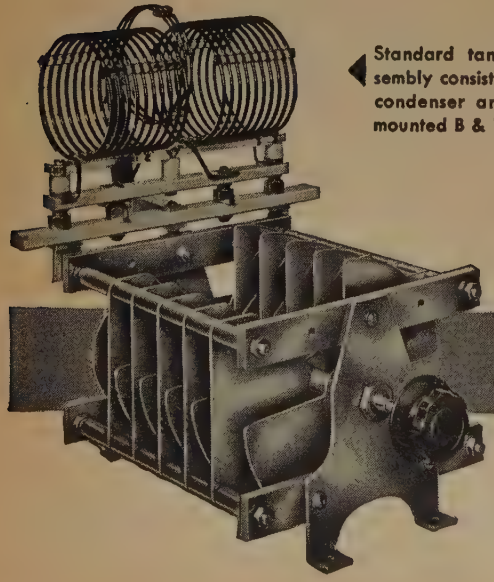
**UNION STATION BUILDING · ERIE, PENN.**

# *Here's* VARIABLE CONDENSER *Efficiency!*

- Perfect electrical design symmetry.
- Built-in neutralization.
- Unexcelled mechanical construction.
- Built-in coil mountings with lead lengths at an absolute minimum.
- Half the length of conventional dual condensers.
- Unexcelled for use in balanced single-ended or push-pull circuits.

▲ A B & W heavy-duty Condenser with ⅛" plates.

*Write for new Catalog 75-C on B & W Type CX heavy duty variable condensers*



◀ Standard tank circuit assembly consisting of B & W condenser and integrally mounted B & W coil.

▲ Typical standard Type CX Condenser with 1/16" plates.

AIR INDUCTORS • VARIABLE CONDENSERS
ELECTRONIC EQUIPMENT ASSEMBLIES

B&W

**BARKER & WILLIAMSON**

**Dept. IR-114, 235 Fairfield Ave., Upper Darby, Pa.**

*Export:* LINDETEVES, INC., 10 Rockefeller Plaza, New York, N. Y., U. S. A.

# GI date for a phone call

This G. I. has an important call to make the instant he lands. For the next steps in the gigantic Air Invasion depend upon the reports he sends back . . . on the instructions he receives.

Fortunately, there will be no crowded circuits, no "busy" signals, for on his back this airborne trooper carries the means for instant, dependable Communications. In its way, it's as expertly designed and built as the huge Transport he has just left, as the automatic rifle that he clutches . . . designed and built to give the greatest possible measure of service under the most punishing conditions. It's one of the reasons why our troops are called the most superbly equipped in the world.

★ ★ ★

*Supplying Transformers, Coils, Headsets and special Electronic parts is the wartime job of Rola, pioneer manufacturer of Sound-Reproducing Equipment.*

THE ROLA COMPANY, INC.
5530 SUPERIOR AVENUE • CLEVELAND 14, OHIO

ROLA

MAKERS OF THE FINEST IN SOUND REPRODUCING AND ELECTRONIC EQUIPMENT

# BETTER TUBES, 13% CHEAPER...

# LOOK AT THE RECORD!

AVERAGE COST PER PREFERRED TYPE TUBE

*November 1939 average cost = 100; all costs based on same tube types

## WHY YOU'RE SURE OF BETTER TUBE PERFORMANCE AT LOWER COST IF YOU BASE POSTWAR DESIGNS ON RCA PREFERRED TYPE TUBES

BUY WAR BONDS

**JANUARY, 1940**— To provide higher quality tubes, and reduce costs at the same time, RCA introduced the Preferred Type Tube Program. The idea was to concentrate a larger demand and production on fewer tube types. The longer manufacturing runs which would result, meant greater production efficiency . . . more uniform, lower-cost tubes for you.

**NOVEMBER, 1940**— The average cost to you of tubes on the RCA preferred list was already 13% lower than that of the same tubes in November, 1939...before the program started. Yet the tubes had *improved* in quality and performance. And fewer types meant simpler tube stocking for both the manufacturer and the dealer-serviceman.

**DECEMBER, 1944**— Another record has since substantiated the value of the preferred type idea . . . that of military equipment designed almost entirely around an Army/Navy Preferred List of Vacuum Tubes. From Saipan to Soissons, our fighting men have been sure of speedy replacements of high-performance tubes.

**V-DAY, 194X**— Look to RCA for continuing the Preferred Type Program after Victory. If you already have specific tube complements in mind for post-war and would like to know if the tubes you plan to use will be on RCA's preferred list, write (stating tube types) to RADIO CORPORATION OF AMERICA, Commercial Engineering Section, Dept. 62-13P, Harrison, New Jersey.

*The Magic Brain of all electronic equipment is a Tube... and the fountain-head of modern Tube development is RCA.*

1919
1944

RCA

25 Years of Progress in Radio and Electronics

62-6131-13

**LISTEN TO "THE MUSIC AMERICA LOVES BEST," SUNDAYS, 4:30 P.M., E.W.T., NBC NETWORK**

**RADIO CORPORATION OF AMERICA**

RCA VICTOR DIVISION · CAMDEN, N. J.

# trace THIS FIGHTER'S RECORD BY HIS MEDALS!

"Captain Dag"

If there were decorations for industrial heroes, Mr. Dag would be a much be-ribboned gentleman. Perhaps we should call him 'Captain' Dag, because he commands so versatile a company of physical and chemical properties.

Captain Dag (a campaigner who will never be mustered out) represents Dag brand colloidal graphite, the smooth, black liquid concentrate which serves so many different war industries. Capt. Dag may take the form of a dry film, a fluid film, a surface coating, an impregnation, etc.

1, 3, 8, 14, 13, 6

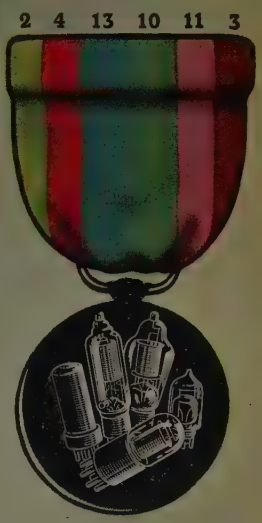
CITATION: "We have been enthusiastic users of Dag colloidal graphite for more than ten years. We find it the only material which will prevent bolts, nuts and flanges from seizing under the high temperature and pressure conditions in our boilers and steam systems."

1, 3, 13, 14

CITATION: "Dry films formed from Dag colloidal graphite supply durable lubrication on parts which could not be effectively lubricated otherwise. Such films are functioning at temperatures from (—60° F. to +1200° F.) and higher."

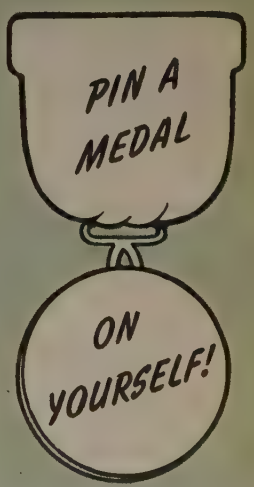
## PHYSICAL AND CHEMICAL PROPERTIES

1. Slippery—A Good Lubricant. Softer than Talc
2. Conducts Electricity
3. Withstands Temperature Extremes
4. Absorbs, Radiates and Conducts Heat
5. Maximum Purity
6. Low Coefficient of Expansion
7. Particles Bear Like Electric Charges
8. Insoluble in Acids and Alkalies
9. Black and Opaque
10. Gas Adsorbent
11. Little Photoelectric Effect
12. Miscible with Most Fluids
13. Films Adhere Tenaciously and Dry with Sharp Edges
14. Microscopically Fine Particles. Penetrates Fine Pores
15. An Excellent Suspension




2, 4, 13, 10, 11, 3

CITATION: "Graphite films when applied to the grids (and frequently the plates) of radio tubes for receiving and transmitting, are useful for minimizing secondary emission, 'back' emission and photoelectric effects."




For easy reference we've given colors to Captain Dag's most valuable properties. Match these colors with the performance "citations" above. Then pin a medal on yourself for putting Captain Dag to work in your plant. He's one campaigner who won't be mustered out.

Dag, Oildag, Aquadag, Castordag, Glydag and Prodag are registered trade marks of Acheson Colloids Corporation. Copr. 1944 by Acheson Colloids Corp.

dag

ACHESON COLLOIDS CORPORATION

# ELECTRONIC RESEARCH FOR INDUSTRY

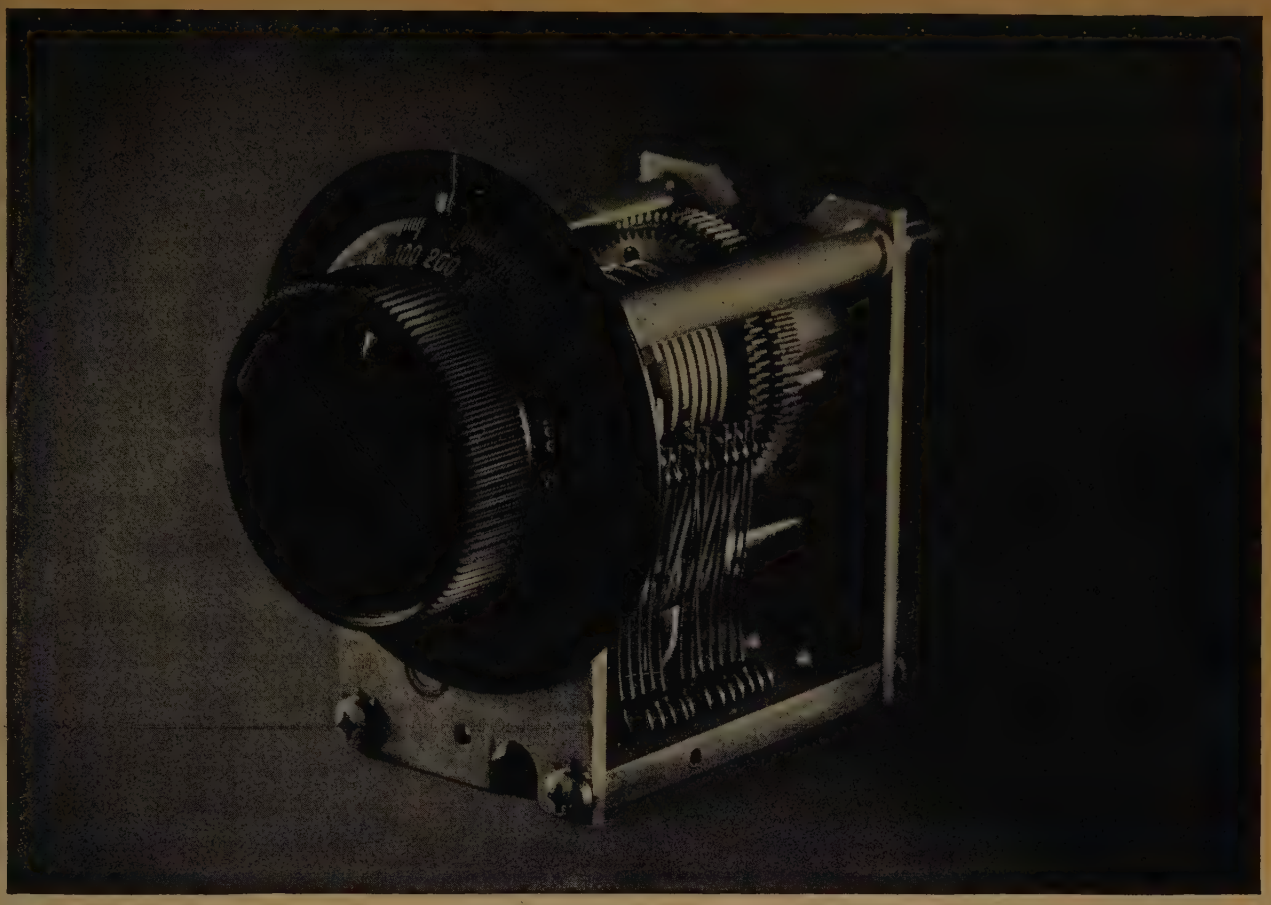
## The National Union Laboratories are now available to complete your established engineering facilities

There is no need to postpone your electronic research program, awaiting the day when competent engineers, costly equipment and scarce materials can be obtained. You can start right now and be far ahead by having National Union Laboratories take over this highly specialized part of your work, thus rounding out the development activities of your existing engineering group.

Whether you are interested in a single project or a complete service—we invite you to investigate National Union Electronic Research. Let's talk it over. There is no obligation whatever. Please address inquiries to Department D.

**NATIONAL UNION RESEARCH LABORATORIES**

**National Union Radio Corporation** **Newark 2, New Jersey**



# COLLINS AUTOTUNE*

## *The Key to Precision Control*

THE Autotune was conceived and engineered by Collins many years ago. It was the result of a growing dissatisfaction with slow, haphazard methods of tuning radio equipment and a persistent effort to improve them.

What is it? How does it work?

The Collins Autotune head shown above is a mechanical device for turning a control shaft and stopping it precisely at any one of several pre-determined positions.

The Collins Autotune system consists of a number of Autotune heads, all driven by a single electric motor, each quickly and simultaneously repositioning a separate and non-interrelated tuning shaft to new settings chosen in advance by the operator. At the touch of a button or flip of a dial, the Collins transmitter or receiver is thus completely and exactly tuned to the wanted channel in a matter of seconds.

Collins communications equipment, Autotune controlled, was adopted by American Airlines, Braniff Airways, Tropical Radio Telegraph Co. and others long before the war. Reliability has been demonstrated through the years under all service conditions.

The Collins transmitter design and the Autotune have proved so advantageous to the Armed Services that military authorities have requested other large companies, in addition to Collins, to build them. The Collins Radio Company, Cedar Rapids, Iowa.

ARMY E NAVY

COLLINS

*U. S. Patents issued and pending.

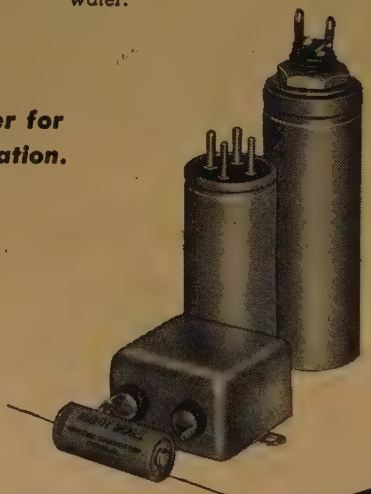
# Unsurpassed QUALITY

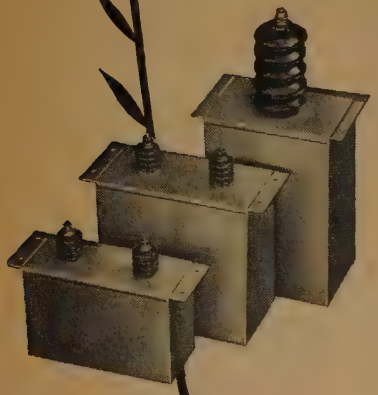
• The Industrial Condenser Corporation manufactures a complete line of Oil-filled, Electrolytic, Wax and Special Mica Capacitors for all industrial, communications and signalling applications up to 250,000 volts working. Complete laboratory and engineering facilities available for solution and design of capacitor problems for special applications.

***An Industrial Condenser for every industrial application.***

**.5 MFD. 50,000 VOLTS DC WORKING**

(Illustrated above)...28 inches high, weight 175 pounds, built by Industrial Condenser Corporation to meet Navy specifications. Oil-filled, oil impregnated. Built for *24 hour continuous operation and total submersion in salt water.*





PAPER, OIL AND ELECTROLYTIC CAPACITORS

**INDUSTRIAL CONDENSER CORPORATION**

3243-65 NORTH CALIFORNIA AVE., CHICAGO 18, U.S.A.

DISTRICT OFFICES IN PRINCIPAL CITIES

# CML SERVES THE ELECTRONIC INDUSTRY

Designed to meet the most rigorous specifications for precision, every CML unit is equipment of accredited performance.

1. ROTOBRIDGE . . . This automatic inspector checks for proper wiring, correct resistance, capacity and inductance values in all types of electronic equipment.
2. MODEL 1100, MODEL 1110 . . . Voltage regulated power supply units: with extremely low noise level and excellent regulation.
3. MODEL 1420 GENERATOR . . . Furnishes test power over a wide frequency range: may also be employed in 3-phase circuits.
4. MODEL 1200 STROBOSCOPE . . . Stops motion within range of 600 to 600,000 R.P.M.

WRITE FOR DESCRIPTIVE BULLETINS

**COMMUNICATION MEASUREMENTS LABORATORY**

120 GREENWICH ST., NEW YORK 6, N. Y.

***Immediate Delivery!***

# WIDE RANGE VACUUM TUBE VOLTMETERS

- High input impedance for both AC and DC measurements.
- Convenient, low capacity "Probe" especially adapted to high frequency radio use—100 megacycles and over.
- Self-regulating operation from power line; no batteries.
- Multiple voltage ranges — accurate and stable.

*BULLETIN ON REQUEST*

**ALFRED W. BARBER LABORATORIES**

34-04 Francis Lewis Blvd. Flushing, N.Y.

YOU are probably voting now for these and other candidates . . . because yours is the big job of knowing the properties of many new materials and the new applications of others.

In designs for tomorrow's radio parts and cabinets, in electronic equipment now winning the war, in pre-war radios, Masonite* Presdwoods appear in astonishing versatility.

Presdwoods by Masonite are ligno-cellulose hardboards made from exploded wood. This grainless material has been used for chassis plates and parts for speakers, baffles, aerial supports, turn tables, copper clad shield panels for field transmitters and for cabinets.

Specific new uses naturally get no publicity. But when you realize that the Presdwoods are a basic commodity—awaiting your orders for future uses, then you may wish to join those who are making Masonite Presdwoods do industrial jobs better.

These are some of the properties and characteristics of Masonite Presdwoods:

high structural strength
moisture resistant
non-corroding
smooth, light, thin, hard
an excellent base for laminated finishes
provides good bond and surface for all forms of decoration
may be punched, die-cut or machined
can be bent into many shapes
economical

For samples and further information, regarding Masonite Presdwood, write Masonite Corporation, Dept. PI-10, 111 W. Washington St., Chicago 2, Illinois.

*"*Masonite*" *is a trade-mark registered in the U. S. Pat. Off., and signifies that Masonite Corporation is the source of the product.*

**MASONITE* CORPORATION**

Reg. U. S. Pat. Off.

Copyright, 1944, Masonite Corporation

## VACUUM TUBE DESIGNER

An Eastern manufacturer has an attractive opportunity for a graduate physicist or electrical engineer with several years of practical experience in vacuum tube design. It is necessary that applicants have sufficient production experience to develop designs which will improve quality and reduce cost through lowered shrinkage.

Furnish full details regarding experience, education, age, and salary requirements.

Write to: BOX NO. 361

THE INSTITUTE OF RADIO ENGINEERS

330 West 42nd St. New York 18, N.Y.



## EXPERIENCED ELECTRICAL ENGINEERS

Graduate or non-graduate Electrical Engineers with at least three years of recent radio circuit or laboratory experience are needed for the development and design of pocket size radio and audio frequency equipment. The company is well established in the electronics field and offers the right man a salary dependent on his experience and also the opportunity to grow in a relatively new field. The company is located in the suburbs of a large New England City.

Write to—

Box no. 358

THE INSTITUTE OF RADIO ENGINEERS

330 West 42nd Street

New York 18, N.Y.


## POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. .....

**The Institute reserves the right to refuse any announcement without giving a reason for the refusal.**

### PROCEEDINGS of the I.R.E.

**330 West 42nd Street, New York 18, N.Y.**

#### ELECTRONIC ENGINEER

Electronic engineer or physicist for developmental work.

Also, electronic technician for construction work on radio test equipment.

Post-war future in both positions. Write to Premier Crystal Laboratories, 63 Park Row, New York 7, N.Y.

#### ASSISTANT PROFESSORS

Assistant professors or instructors in electrical engineering to specialize in electronics, communications, and illumination. Strong eastern engineering college. Submit professional record and photograph with application. Positions permanent. Address Box 362.

#### ELECTRONIC ENGINEERS AND DRAFTSMEN

The services are required of several electronic equipment design engineers capable of supervising the system layout of electronic and electro-mechanical devices.

Also, several draftsmen are needed with experience in electronic schematics, circuit layouts, and wiring diagrams, or with considerable experience in other related electrical fields.

Write giving full qualifications to the Personnel Department, Curtiss-Wright Corp., Development Division, 88 Llewellyn Ave., Bloomfield, N.J.

#### CONSULTING ENGINEERS

For laboratory with adequate facilities to take on the design of R.F. precision measuring instruments on a contract basis. Send reply to Box 359.

#### ELECTRONICS ENGINEERS

Development engineers on television and ultra-high-frequency tubes. Technician on tubes. Radio engineers on special applications.

Write full details to Box 363.

#### ELECTRONIC EXPERT

Needed in management of large New York plant. Capable of supervising manufacture of transmitting and receiving radio assemblies, transformers and other electronic equipment. Excellent opportunity. Write personal and professional qualifications, salary expected, to Box 210, Suite 1024, 122 E. 42 St., New York 17, N.Y.

#### ELECTRONIC ENGINEER

Radio or electronic engineer for design and development of Army and Navy electronic equipment. Position offers excellent opportunity with well established and expanding company in Connecticut, employing over one hundred personnel. The company's big post-war program in the industrial electronics, radio, and aircraft communications fields assures engineering personnel a continued opportunity for advancement. Address reply to Box 364.

#### RADIO ENGINEERS, SUPERVISORS AND TECHNICIANS

Chief Radio Engineers, Transmitter and Studio Supervisors and Technicians between thirty and forty-five years of age are needed at once in important war work in the Pacific to construct and operate radio stations. These positions are with the United States Government, with good salaries and subsistence, and for the duration plus six months. Interested persons with actual broadcast experience should write, giving details of radio work, to Box 356.

#### RADIO, ELECTRICAL AND MECHANICAL ENGINEERS

In the development and production of all types of radio-receiving and low-power transmitting tubes. Excellent post-war opportunities with an established company in a field of opportunities. Apply in person, or write to Personnel Manager of Raytheon Manufacturing Company, 55 Chapel Street, Newton, Mass.

*(Continued on page 52A)*


## ENGINEERS JUNIORS and SENIORS

**For research and Development work in Electronics**

**EE DEGREE**

●

**3 to 5 years experience desirable. Excellent opportunity with one of America's Foremost Electronic Laboratories.**

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**HAZELTINE CORPORATION**

**58-25 LITTLE NECK PARKWAY**

**Little Neck, Long Island, N.Y.**



## CHIEF BROADCAST RECEIVER ENGINEER

Large eastern radio manufacturer has an opening for a Chief Engineer in its Broadcast Receiver Section. Excellent opportunity for the right person. Must have adequate experience and background. Salary $8,000 to $12,000 per year depending upon ability and experience of applicant.

War Manpower Commission Regulations Apply.

Address all replies to:

**BOX NO. 360**

**THE INSTITUTE OF RADIO ENGINEERS**

**330 West 42nd St.**

**New York 18, N.Y.**

# CHECK TRANSMITTER FREQUENCY IN LESS THAN A MINUTE

***THE BROWNING FREQUENCY METER,** used by police and other emergency radio facilities for the past five years, is still the best meter for such services — because it was specifically designed for them. The design, which permits determination of any five frequencies from 1.5 to 120 Mc., makes for simplicity of operation which requires less than one minute to check one frequency. All Browning development work aims at specific, rather than broad, uses. Thus, all Browning equipment is best for its particular job. Furthermore, Browning Laboratory facilities are available for study and solution of your own, specific electronic engineering problems. Write for data.*

# BROWNING

LABORATORIES, INCORPORATED

WINCHESTER, MASSACHUSETTS

# An Opportunity awaits

## ENGINEERS
## DESIGNERS
## TECHNICIANS

at **FRIEZ** Instrument Division

***Bendix Aviation Corporation***

Through 69 years of Peace and War, the name FRIEZ has been synonymous with precision instruments throughout the world. As a division of Bendix Aviation, FRIEZ has pioneered in Electronic, Mechanical and Control fields.

To carry forward this essential war work, as well as to project our war facilities into peacetime fields, calls for a high order of engineering skill . . . an opportunity and a challenge to

**ENGINEERS, DESIGNERS, TECHNICIANS**

We have openings in these groups that should interest both graduate engineers of long experience as well as recent graduates.

Tell us in which of these fields you have specialized. Or if a recent graduate, for which of these fields you would be best adapted.

Your letter of inquiry will be assured strict confidence. Tell us as much as possible about yourself, and we will in turn send you complete details of a FRIEZ job in which your professional abilities will be profitably employed.

***Write Today to: CHIEF ENGINEER***

**FRIEZ**

**INSTRUMENT DIVISION**
**BENDIX AVIATION CORP.**
**1231 E. LAFAYETTE AVE., BALTO, MD.**

**HIRING SUBJECT TO WAR MANPOWER REGULATIONS**


## POSITIONS OPEN

*(Continued from page 50A)*

### RADIO ENGINEERS

Need radio engineers with experience in Frequency-Modulation transmitting and receiving equipment. Familiarity with F.C.C. rules and field operation of equipment desirable. Send complete experience and education in letter of application, and state salary desired. Company located in the Midwest where living conditions are good, and expenses below average. Address to Box 351.

### RADIO ENGINEER

Unusual opportunity for experienced radio engineer. Well established medium-size Midwest radio manufacturer. Large post-war program. Nationally advertised radio line. Write qualifications and experience to the Agency Service Corporation, 66 East South Water Street, Chicago 1, Ill.

### VACUUM-TUBE DESIGNERS

Engineers and physicists for research and development work on small vacuum tubes.

An opportunity for post-war employment with a growing organization doing both war and essential civilian production. Recent graduates with adequate training and experienced personnel will be considered for these positions.

Certificate of availability required. Write to Director of Research, Sonotone Corporation, Elmsford, N.Y.

### ELECTRICAL ENGINEERS

Needed in connection with the manufacture of a wide variety of new and advanced types of communications equipment and special electronic products. Openings available in St. Paul, Minn., Eau Claire, Wis., and Chicago. Apply or write, giving full qualifications and furnish snapshot, to D. L. R., Employment Department, Western Electric Company, Hawthorne Station, Chicago 23, Illinois.

*(Continued on page 54A)*


## Electronic Engineers
## Mechanical Designers

●

Manufacturer of Electronic equipment seeks the services of qualified Electronic Engineers and Mechanical Designers for development and research work on high quality AM-FM Radiophonographs. Extensive experience required in Design Engineering of Electronic equipment, including receiver, radio chassis and dial mechanisms. Engineering degree desirable but not essential. Excellent opportunities. Please submit resume.

●

**PHILHARMONIC RADIO CORPORATION**
**528 East 72nd Street**
**New York 21, N.Y.**

TRANSMITTING TUBES
VACUUM CONDENSERS

# HIGH VACUUM CONDENSERS

# VC 50 TO 250 give higher efficiency

Photograph shows Jennings Condensers passing through induction heating coils on the automatic rotary high vacuum pumps where the present large production is meeting the exacting requirements of the U. S. Signal Corps Transmitters and the advanced standards of

## MODERN ELECTRONIC HEATING EQUIPMENT

Jennings Vacuum Condensers and Transmitting Tubes are used in many critical communication operations in all theatres of war. In the South Pacific where dampness and tropical heat cause corrosion and deterioration, Jennings Vacuum Condensers are helping the Signal Corps ***TROPICALIZE**** their Transmitting Equipment. Electronic Engineers realize the importance of this protection in choosing Jennings Condensers for their transmitters now in development.

* Prevents corrosion and deterioration

**TROPICALIZE YOUR EQUIPMENT WITH JENNINGS UNITS**
**Literature will be sent on request**

***JENNINGS RADIO MANUFACTURING COMPANY, Dept. P***

**1098 EAST WILLIAM STREET • SAN JOSE 12 • CALIFORNIA**

## Design and Development
## RADIO ENGINEERS
## WANTED

This laboratory plans to add a number of experienced radio engineers to its staff. Particularly desired are men with advanced radio and television circuit development background.

Openings for recent graduates as student or junior engineers are also available.

Salaries will be commensurate with training and experience. All positions are permanent.

WMC regulations apply.

Make application by letter giving complete details of your qualifications or in person to—

**Industry Service Division of**
**RCA Laboratories**
(License Laboratory)
711 Fifth Ave., New York 22, N.Y.


## POSITIONS OPEN

(Continued from page 52A)

### ELECTRONIC SALES ENGINEERS

Established electronic tube manufacturer, located in Midwest, requires sales engineers to cover Midwest or East Coast. Applicants should have electrical-engineering degree, knowledge of electronic circuits and applications, and ability to contact customers. Excellent wartime and postwar opportunity for the right men. Salary and bonus. Send complete information to Box 346.

### ELECTRICAL ENGINEER

Electrical engineer wanted for position of chief of research and development section of a Metropolitan New York division of nation-wide manufacturer. Must have a sound educational background and outstanding design experience on light equipment. Salary open. Reply in confidence giving complete personal data, experience résumé, availability for release, etc. to Box 348.

### FIELD SERVICE ENGINEERS

For domestic and foreign service. Must possess good knowledge of radio. Essential workers need release. Write to Haseltine Electronics Corporation, 58-25 Little Neck Pkwy., Little Neck, L.I., N.Y.

### AUTO-RADIO-SET DESIGNER

An auto-radio-set design engineer with pre-war experience needed immediately for post-war development. Write fully, outlining experience, salary expected, etc. Address your letter to Box 341.

### DESIGNER

A central New England manufacturer employing over 1000 people needs draftsman-designer on telephone and signaling (mechanical) apparatus.

Knowledge of die-casting and plastic applications desirable. WMC regulations prevail. Write to Box 339.

(Continued on page 58A)


## CHIEF LOUD SPEAKER ENGINEER

The Rola Company, Inc. requires the services of an Engineer who has had several years experience and capable of heading this division.

Present work is on 100% urgent war products.

Excellent post-war opportunity with an outstanding, financially sound, long-established manufacturer of radio loudspeakers and transformers.

This Company now has definite plans for an extensive expansion in its Engineering and Manufacturing Divisions.

Salary open.

**Write to**
**The Rola Company, Inc.**
**2530 Superior Avenue**
**Cleveland 14, Ohio**



## EXCEPTIONAL OPPORTUNITY
for
## Experienced Radio Engineers
and
## Technical Writers

One of America's largest transmitter manufacturers located in the Middle-west has openings on its engineering staff for experienced radio engineers and technical writers. The engineers will be offered an opportunity to work on the most advanced type of military equipment and will participate in extensive post-war development plans. We will be particularly receptive to applications from men experienced in airline radio and railroad communications work.

The technical writers should be experienced in preparing instruction manuscripts to Army and Navy specifications. They will also be required in the post-war period to write similar material for commercial applications and technical copy for trade publications.

Ideal working conditions. Salary rate commensurable with ability. State age, experience, education, and references. Address replies to

Chief Radio Engineer
AIRCRAFT ACCESSORIES CORPORATION, ELECTRONICS DIVISION
Fairfax and Funston Roads, Kansas City, Kansas



## ENGINEERS
**For Design & Development Radio-Television**

Degree in communications engineering or equivalent in radio design essential. Post war permanence assured right men.

Write full qualifications—education, experience and status of availability.

**Box No. 353**
**Proceedings of the I.R.E.**
**330 West 42nd Street,**
**New York 18, N.Y.**

*You can depend upon these* **DIRECT READING** **INSTRUMENTS**

**in development, research, design and production of radio and allied equipment**

**Q-METER**

### TYPE 160-A

Frequency Range: 50kc. to 75mc. may be extended with external oscillator down to 1 kc.
Range of Q Measurements, Coils: 50 to 625.
Accuracy: in general ± 5%
Range of Q Tuning Condenser: 30-450 mmf. (Vernier Condenser: ± 3 mmf.)

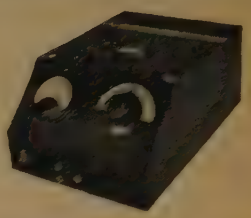
**Q-METER**

### TYPE 170-A

Frequency Range: 20mc. to 200 mc.
Range of Q Measurements, Coils: 100-1200
Accuracy: in general ± 10%
Range of Q Tuning Condenser: 10-60 mmf.

**QX CHECKER**

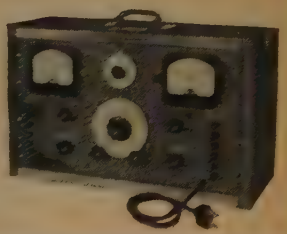
### TYPE 110-A



The factory counterpart of the Q-Meter. Compares fundamental characteristics of inductance or capacitance and Q under production line conditions with a high degree of accuracy, yet quickly and simply. Insures uniform parts held within close tolerances. Frequency range 100 kc. to 25 mc.

**FREQUENCY MODULATED SIGNAL GENERATOR**

### TYPE 150 SERIES



Type 150 A—Frequency 41-50 mc. and 1-10 mc.
Type 151 A—Frequency 30-40 mc. and 1-9 mc.
Type 152 A—Frequency 20-28 mc. and 0.5-5 mc.
Type 154 A—Frequency 27-39 mc. and 1-7 mc.
Developed specifically for use in design of F.M. equipment. Frequency and Amplitude Modulation available separately or simultaneously.

**BEAT FREQUENCY GENERATOR**

### TYPE 140-A

A single compact instrument which provides wide frequency and voltage coverage of generated signals.
Frequency Range: 20 cycles to 5 mc. in two frequency ranges.
Output Voltage Range: 1 millivolt to 32 volts.
Accuracy: ± 3%.
Output Power: One watt into external load.

**BOONTON RADIO** *Corporation* BOONTON, NEW JERSEY.

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(Appeared serially in *Instruments* from August 1941 to June 1943)

By

JAMES SPENCER

In charge of Instrument and Relay Department, Meter Division, Westinghouse Electric & Manufacturing Co., Newark, N.J.

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This reprint should be of great value to all those whose problem it is to keep in operation the electrical instruments on vital war production as well as those on planes, signal equipment, tanks, ships, guns and other armament.

The electrical instrument industry has expanded more than 30 times its normal production, but its service facilities in general have not kept up with this pace. Some electrical instrument manufacturers do practically no servicing and cannot promise early return of the few instruments they accept for repairs.

This reprint should be useful to all instrument users, switchboard attendants, testing engineers, and instrument service men, as the accuracy and efficient life of instruments depend to a large extent on competent handling.

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Breadboards are nothing new to housewives . . . or to radio. But to teach one about the other has been one of the minor problems created by the war.

Ample proof that the housewives have learned their lesson well is to be found in the volume production of radio assemblies at Pacific Division.

To these girls also must go credit for the important part they play in maintaining the excellence of workmanship which has always been associated with Pacific Division products.

And so Pacific Division continues to offer this friendly challenge—in manufacture and assembly, as well as in engineering, there is no finer product than the one Pacific Division produces.

Pacific Division
BENDIX AVIATION CORPORATION
NORTH HOLLYWOOD, CALIFORNIA

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## *by* STUPAKOFF

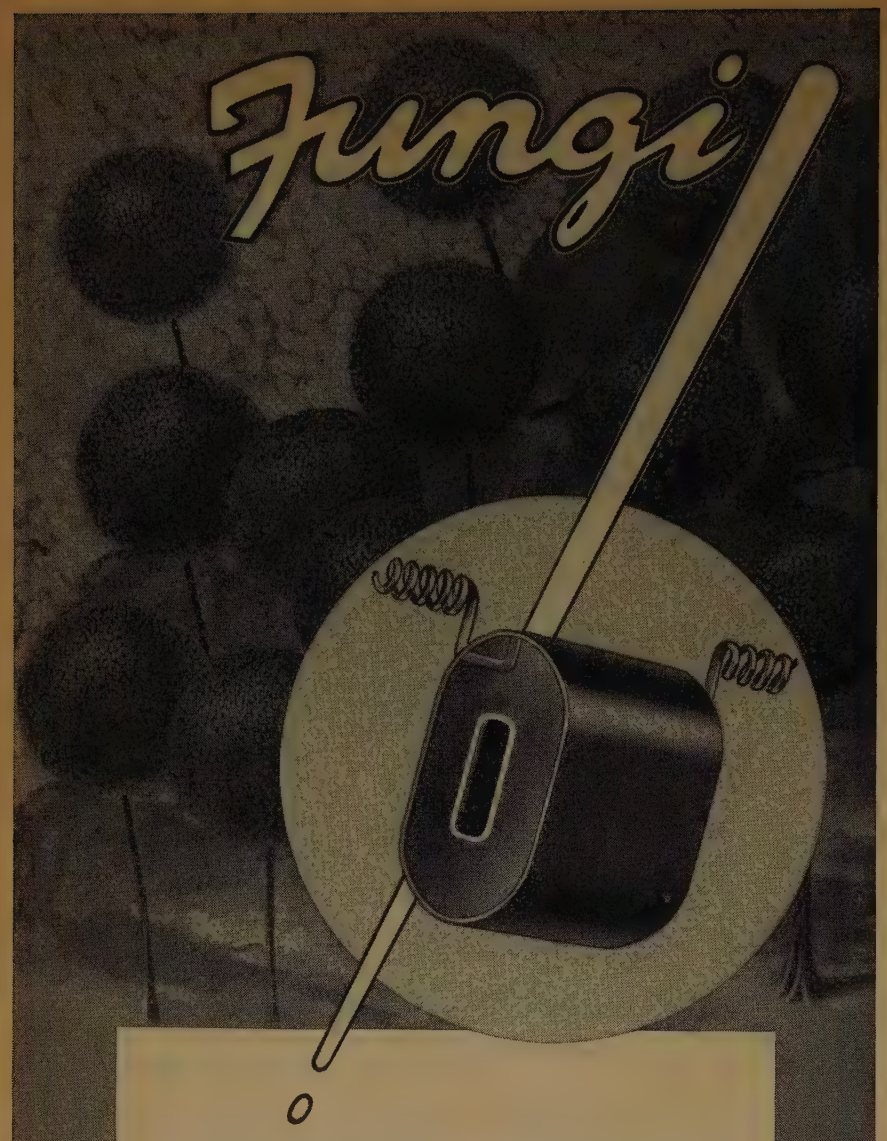
To overcome the weaknesses in coil forms with cemented bases, Stupakoff manufacturing ingenuity has produced single unit construction. The illustrated result — coil forms of optimum mechanical and insulating properties that assure permanence and stability in operation. Vibration and humidity tests prove the superiority of this design.

Backed by two generations of experience in the manufacture of precision ceramics, Stupakoff engineers will give dependable assistance in developing insulators for your electronic apparatus. An inquiry will put our technical knowledge and manufacturing facilities at your disposal.

Do More Than Before—Buy EXTRA War Bonds

**STUPAKOFF CERAMIC AND MANUFACTURING CO., LATROBE, PA.**

*Ceramics for the World of Electronics*




## Deadly Agents of Destruction

This is not a balloon barrage. It is an actual photograph, highly magnified, of parasitic organisms (fungus growths), the control of which poses one of the toughest problems our armed forces have to contend with in keeping electrical and communication equipment in operation.

If your present contracts utilize electrical coil windings, and call for "tropicalization" or "anti-fungus" treatments, our 27 years of experience are at your service to provide proper coil design and treatment.

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# Positions Open

*(Continued from page 54A)*

### DEVELOPMENT ENGINEERS

Mechanical and electrical. Graduate or equivalent training. Required for development work in the following branches:

1. Electro-mechanical devices, communication systems. Must be interested in development and familiar with magnetic circuits.
2. Measuring and control instruments. Background should be in electrical engineering, including electronics.

Statement of availability required. Address Box 340.

### RADIO-ELECTRONIC ENGINEERS

A young progressive radio-electronic firm needs top-flight men for these key positions:

Electronic engineers and technicians
Electro-mechanical engineers, familiar with mechanical design of electrical and electronic equipment
Chief inspector
Supplier's contact engineer
Master mechanic
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Project engineers

Engaged 100% in war work, with excellent post-war future and possibilities. Our staff knows of these openings. Write in confidence to Box 352.

### ELECTRICAL ENGINEERS

Electrical engineers for research and development in the field of radio communications and electrical test equipment. Good post war opportunity. Address reply to Allen D. Cardwell Mfg. Corp., 83 Prospect Street, Brooklyn, N.Y.

*(Continued on page 60A)*

### RESEARCH ENGINEERS

For development work on electro mechanical servo mechanisms and communication equipment. Prefer A-1 men who can take charge of complete projects. Salary commensurate with ability. Permanent positions with excellent post-war opportunities. Address replies to Box 357.

The foregoing positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. .....


## *Wanted*
# ENGINEERS

**Radio**
**Chemical**
* **Electrical**
**Electronic**
* **Mechanical**
**Metallurgical**
* **Factory Planning**
**Materials Handling**
**Manufacturing Planning**

**Work in connection with the manufacture of a wide variety of new and advanced types of communications equipment and special electronic products.**

***Apply (or write), giving full qualifications, to:***

R.L.D.
EMPLOYMENT DEPT.

## *Western Electric Co.*

100 CENTRAL AVE., KEARNY, N.J.

*Also: C.A.L.
Locust St., Haverhill, Mass.

Applicants must comply with WMC regulations

# 2 POPULAR RCA INSTRUMENTS
## for high-precision measurement work

**RCA High-Frequency Wide-Band Sweep Generator** *Type 709 B*

**RCA Ultra-High Frequency Signal Generator** *Type 710 A*

THE big job is done—valuable development, production and field test experience are combined in two quality products—the 709 B Sweep Generator and the 710 A Signal Generator. Here are two instruments every Television, FM and H.F. Laboratory can rely on for postwar design applications.

The 709 B Sweep Generator covers the frequency band of 5 to 65 megacycles (center frequency). It is ideal for high frequency I. F. curve response study. Its calibration marker permits constant checking of band width characteristics.

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Planning your postwar activity means planning your laboratory facilities as well. Now is the time to investigate the characteristics of these reliable RCA instruments.

*RCA bulletins containing complete descriptions and specifications of the 709 B Sweep Generator and the 710 A Signal Generator will be sent promptly on request.*

*Please note that deliveries of these instruments are subject to regulations of WPB General Scheduling Order M-293.*

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## SENIOR ELECTRONIC ENGINEERS

Preferably graduates of communication engineering courses are required for designing, receiving-type electronic equipment covering all frequency ranges, and other specialized electronic apparatus. Design experience necessary and knowledge of production is desirable. Excellent post-war opportunities. Salary open. Requirements urgent. Proof of citizenship and certificate of availability are necessary.

Write giving detailed qualifications and if satisfactory, interview will be arranged at our expense.

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WE ARE not going to tell you here why this tube was made, what it does, or what it is for. The important thing about it to you as a user of radio oscillator, amplifier and rectifier tubes for communications or induction heating is that it represents the toughest assignment ever handed the electronic tube industry, and that of all tube makers only Machlett perfected the techniques that made the tube possible.

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The perfection of this 2,000,000-volt direct-current tube is the best proof we can offer of the value of the Machlett skills that go into the design and manufacture of every tube bearing our name . . . Machlett Laboratories, Inc., Springdale, Connecticut.

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| 54 | 62 | 76 | 119 | 159 |
| 55 | 63 | 77 | 120 | 160 |
| 56 | 64 | 104 | 124 | 291-A |
| 58 | 65 | 108 | 125 | 354 |
| 59 | 67 | 109 | 127 | |
| 60 | 68 | 112 | 149 | |

| PLP | | PLQ | | PLS | |
|---|---|---|---|---|---|
| 56 | 65 | 56 | 65 | 56 | 64 |
| 59 | 67 | 59 | 67 | 59 | 65 |
| 60 | 74 | 60 | 74 | 60 | 74 |
| 61 | 76 | 61 | 76 | 61 | 76 |
| 62 | 77 | 62 | 77 | 62 | 77 |
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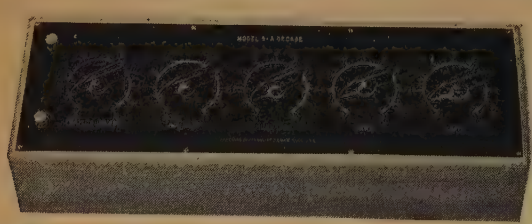

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**The CREI NEWS, monthly house organ published by the Capitol Radio Engineering Institute, is now presenting an interesting series of technical articles on the subject of Circuit Equivalents.**

**The current article takes up actual circuit equivalents. These include such elements as speaker dividing networks, high-frequency resistors of large power dissipation for use in high-level video amplifiers, rhombic antenna termination, and finally, an example from the acoustic field, that of the rubber transmission line used in a disc recorder.**

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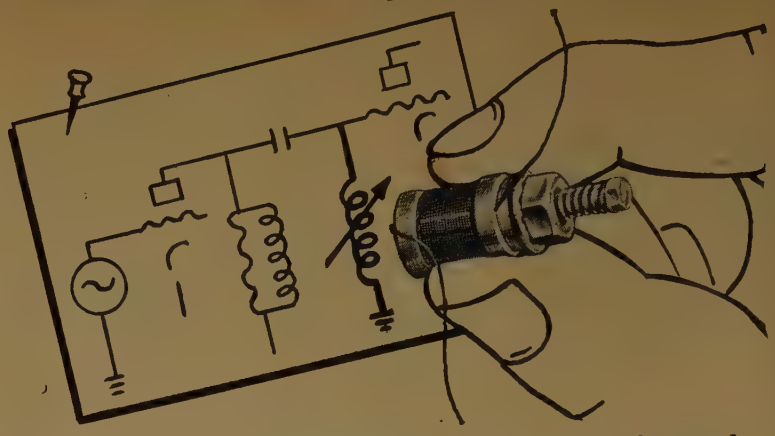

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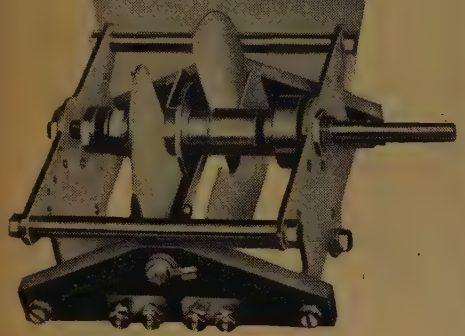

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economical cost are "duck soup"

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us what physical properties are

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*required, and we'll quickly tell you*

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whether Laminated Plastics can

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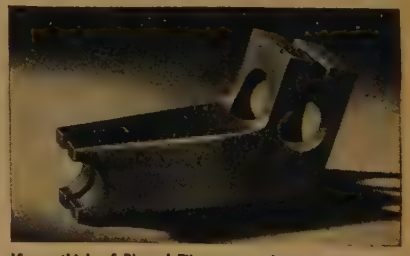

If you think of Phenol Fibre as a plastic that can be used only for the simpler types of insulation, look at this high-finished radio slider that is drilled, slotted, and beveled into just about as complicated a piece of equipment as you'll find in any electrical device. Taylor ingenuity and Taylor equipment turn out such pieces by the thousands at remarkably low cost. Before you decide "it can't be done," Take it to Taylor.

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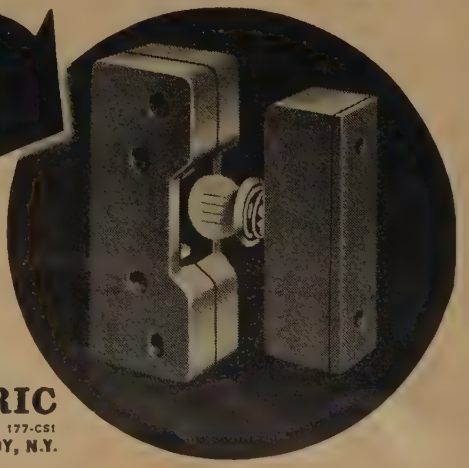

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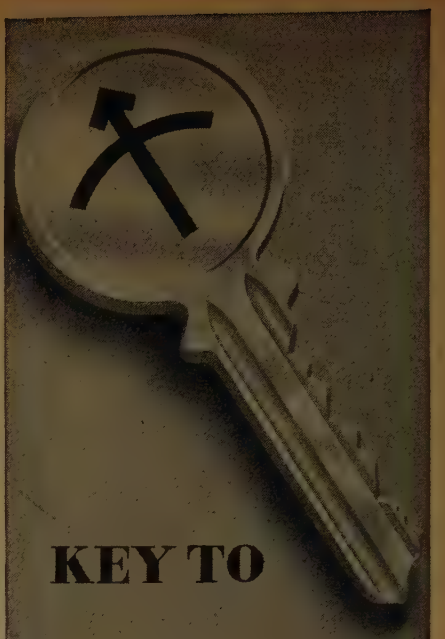

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# INDEX


Section Meetings ..... 34A

Membership ..... 36A

Positions Open ..... 50A


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Aerovox Corporation ..... 11A
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Alliance Mfg. Co. ..... 34A
American Lava Corp. ..... 43A
American Telephone & Telegraph Co. ..... 23A
American Transformer Co. ..... 5A
Amperex Electronic Corp. ..... 69A
Andrew Co. ..... 70A
Arnold Engineering Co. ..... 60A
Audio Development Co. ..... 36A
Automatic Winding Co., Inc. ..... 37A

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Barker & Williamson ..... 30A
Rex Bassett Inc. ..... 62A
Bendix Aviation Corp., Pacific Div. ..... 56A
Bliley Electric Co. ..... 29A
Boonton Radio Corp. ..... 55A
Browning Laboratories, Inc. ..... 51A

Cambridge Thermionic Corp. ..... 66A
Capitol Radio Engineering Institute ..... 66A
Allen D. Cardwell Mfg. Corp. ..... 67A
Centralab ..... 35A
Chicago Transformer Corp. ..... 62A
Cinaudagraph Speakers, Inc. ..... 64A
Clarostat Mfg. Co., Inc. ..... 71A
Sigmund Cohn & Co. ..... 73A
Collins Radio Co. ..... 47A
Communication Measurements Laboratory .... 48A
Communication Products Co., Inc. ..... 64A
Continental Electric Co. ..... 64A
Cornell-Dubilier Electric Corp. .....Cover III
Coto-Coil Co., Inc. ..... 58A

Dejur-Amsco Corp. ..... 19A
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Electro-Voice Corp. ..... 7A

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General Radio Co. .....Cover IV
Goat Metal Stampings, Inc. ..... 67A

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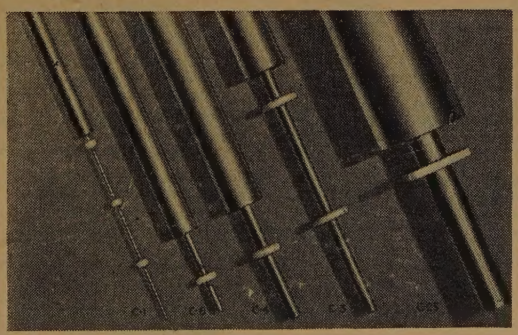

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Oscillator Circuit . Crystal
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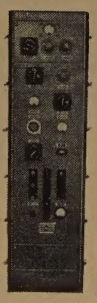
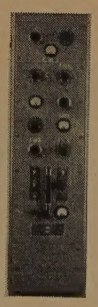
No. of Frequencies . . One
Vertical chassis construction. Built-in modulation indicator. Separate speech amplifier.



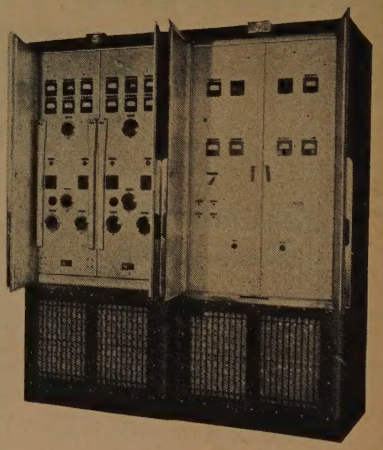
### TRANSMITTER TYPE ET-4335-LF

Frequency Range.....150 to 600 kc.
Oscillator.....Crystal
Power Output.....250 watts Telephone
350 watts Telegraph
No. of RF Channels . One
No. of Frequencies . . One
Modulation indicator and tuning controls on front panel. Built-in speech amplifier, modulator and power supply.



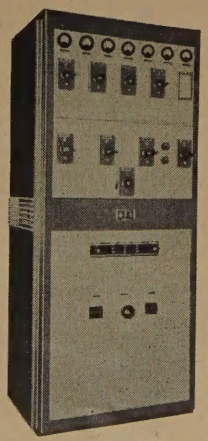
### TRANSMITTER TYPE AVT-22B

Frequency Range.....2650 to 19,000 kc.
Oscillator Circuit.....Crystal or M.O.
No. of Channels.....(Two pictured) May be added as desired
No. of Frequencies.....One per channel
Power Output. 5 kilowatts
Type of Emission.....Telephone or Telegraph
Additional channels may be added as required. Master oscillator available as accessory equipment.



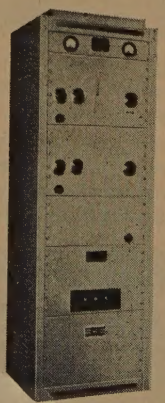
### TRANSMITTER TYPE ET-4331

Frequency Range.....3000 to 20,000 kc.
Oscillator Circuit . Crystal
No. of RF Channels . One
No. of Frequencies . . . Six
Power Output. 1 kilowatt
Type of Emission.....Telephone
High fidelity with audio substantially flat between 50 and 10,000 cycles. Speech inverter for security of messages available as accessory equipment.



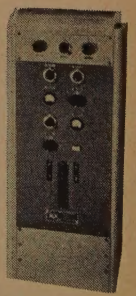
### TRANSMITTER TYPE ET-4339

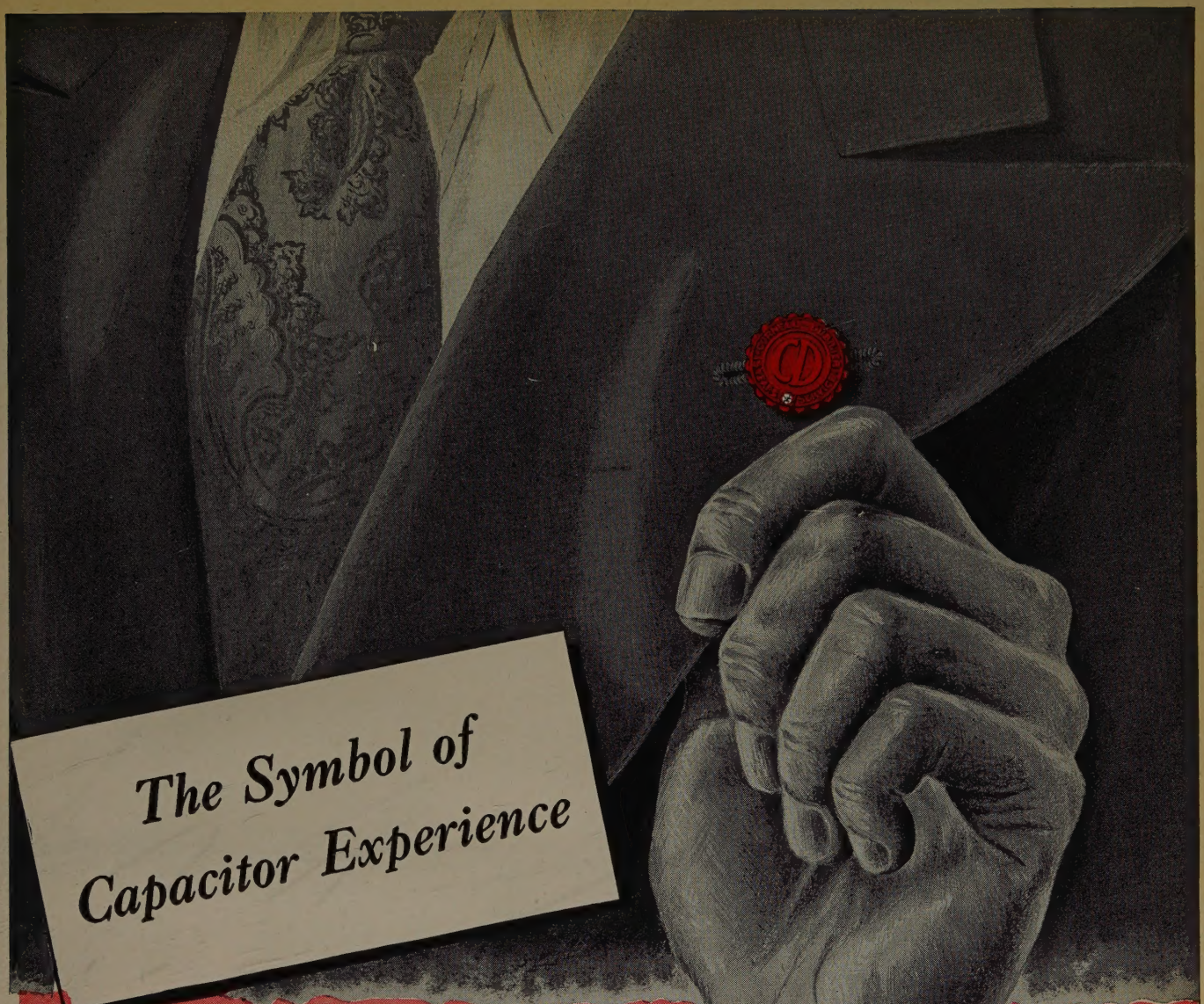
Frequency Range.....1700 to 20,000 kc.
Oscillator Circuit . Crystal
Power Output. 200 watts
Type of Emission.....Telephone and Telegraph
No. of RF Channels . Two
No. of Frequencies . . Four
Single unit construction. Remote control available as accessory equipment.



### TRANSMITTER TYPE ET-4332-A

Frequency Range.....2200 to 20,000 kc.
Oscillator Circuit . Crystal
Power Output.....250 watts Telephone
350 watts Telegraph
No. of RF Channels . One
No. of Frequencies . . One
Vertical chassis construction. Separate speech amplifier.





# *The Symbol of Capacitor Experience*

Pride is something that comes from the heart. It cannot be seen — except as a symbol. Such as these service pins worn by our skilled craftsmen.

C-D's men and women are outstanding technicians in their special field — capacitors. Many of our men have been working on C-D capacitors almost as long as modern capacitors have been in existence . . . for C-D pioneered in capacitors and has manufactured them exclusively for 34 years.

Some of our men designed and made capacitors for wireless equipment used in World War I. They proudly wear their symbols of long service. Others wear their 5-year pins, their 10-year pins, their 20-year pins as a mark of their skill, accumulated knowledge and experience in capacitors.

Our men and women are constantly striving for improvements . . . and out of their inquiring minds come new developments to meet the changing needs of capacitor users. These are the people who build dependability into C-D capacitors — that make them top quality always. Cornell-Dubilier Electric Corporation, South Plainfield, N. J.

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# NEW FREQUENCY METER and MONITOR

## for HIGH FREQUENCY SERVICES—1500 kc to 200 Mc

ARMY E NAVY

For measuring and monitoring the carrier frequency of a-m transmitters, these two new G-R instruments offer many operating advantages over equipment formerly available.

With the Frequency Meter, readings are substantially independent of amplitude of modulation, input waveform and input voltage. Over very wide ranges, changes in any of these do not affect the meter indications. The instrument requires no direct connection to the transmitter . . . a foot or two of wire provides ample coupling. The indicating meter has six ranges with full-scale values of 200 cycles, 600 cycles, 2 kc, 6 kc, 20 kc and 60 kc.

One of the most useful features of the Frequency Monitor is its great sensitivity. It can be used to monitor mobile stations. The numerous operating conveniences include: a panel switch to select any one of four temperature-controlled quartz plates; a "stand-by" control to maintain operating temperature continuously with the tube circuits disconnected; positive indication of the direction of frequency deviation; panel terminals for the audio output and for the output of the crystal buffer stage for calibrating or adjusting transmitters or receivers.

You'll find that this combination of instruments is one of the best G-R has developed for high-frequency communications monitoring.

Because we are in full-time production of war orders, none of these instruments are available for shipment, and probably will not be until after the war. We ARE accepting reservation orders, however, and will fill them in rotation as soon as production starts.

### FREQUENCY METER

**RANGE:** 0 to 60,000 cycles in six ranges

**ACCURACY:** ±2% of full scale

**INPUT VOLTAGE:** Any between 0.25 and 150 volts

**MOUNTING:** Relay-rack panel; walnut end-frames (illustrated) for table mounting, extra

**TYPE 1176-A FREQUENCY METER $185.00**

### FREQUENCY MONITOR

**CARRIER RANGE:** 1500 kc to 200 Mc

**ACCURACY:** 0.003% with our quartz plates

**QUARTZ PLATES:** Up to four, not included in price; ground to channel frequency

**MOUNTING:** Same as Frequency Meter

**TYPE 1175-A FREQUENCY MONITOR.....$250.00**

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